THE THEORY AND PRACTICE OF PROFOUND KNOWLEDGE: AN INQUIRY INTO QUALITY AND STRATEGY MANAGEMENT

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THE THEORY AND PRACTICE OF PROFOUND

KNOWLEDGE: AN INQUIRY INTO QUALITY AND

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Title of Study: THE THEORY AND PRACTICE OF PROFOUND KNOWLEDGE: AN INQUIRY INTO QUALITY AND STRATEGY MANAGEMENT

Major Field: INDUSTRIAL ENGINEERING AND MANAGEMENT

Abstract: This research develops a theory of profound knowledge, derived from the quality dialog between Walter A. Shewhart and W. Edwards Deming. In 1992, Deming introduced his system of profound knowledge as the mechanism by which executives could make organizationally transforming decisions to implement strategic change. He coupled this theory with the Deming Cycle, which represented a change in the Japanese PDCA Control Cycle, focusing on learning and improvement rather than on work process analysis and control. These changes were enigmatic because Deming did not provide academic citations for his system, linkage to his prior theories, or operational definitions for the terms he used. Instead, Deming implied that his prior theories should be perceived as a natural outgrowth of this new system. Thus, the system of profound knowledge only represents a framework for further consideration and not a serious advance in quality thinking.

This research investigates the sources of Deming's system, related to a thinking experiment that he had been conducting with Shewhart since the late 1920s when they first met and began a lifelong association. The nature of their symbiotic thinking is described, and literature is cited to trace the evolution of the four elements in Deming's system—from their nascent beginning in the 1870s, when logical positivism and pragmatism began to influence scientific thinking and merged with probabilistic theory for conducting investigations. Shewhart contributed the core concepts for Deming's system in his theory of control, and his statistical process control methods; however, a host of academics and researchers from such diverse fields as psychology, philosophy, statistics, physics, economics, and engineering contributed related ideas that are integrated into the comprehensive approach to quality which is described here as the theory of profound knowledge.

This research performs two sequential inquiries. First, it develops a scientifically appropriate theory of profound knowledge based on a grounded research analysis of the historical thinking pathways which developed each of the four elements, defining a general model describing the manner in which this theory operates. Second, it uses an expert panel to review and validate the proposed theory and establish its potential for practical application.

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CHAPTER I

INTRODUCTION: INDUSTRIAL ENGINEERING AND EFFECTIVE EDM

This chapter focuses on the research conducted in association with this dissertation and sets expectations for the subsequent inquiry.

1.1 Research Perspective

In his 1992 book, *The New Economics,* W. Edwards Deming (1994), who lived from 1900 to 1993, proposed a system of profound knowledge to achieve the purposeful, executive-directed, transformation of an organization's performance. However, his system was not developed completely before he passed away in 1993, and he only proposed a categorization scheme consisting of four components that he believed were critical to the system, Deming failed to specify how these four elements operate individually and collectively to form a system that fosters transformation in organizations. Furthermore, he cited no prior research to substantiate his claims and provided no practical examples to illustrate the way that he envisioned this system would operate. Deming also never defined the meaning of profound knowledge in operational terms or grounded his theory on an objective foundation. He did not create a logical alternative to his concept of profound knowledge, which would have made it possible for that theory to be substantiated with scientifically accepted studies. Deming did not describe this theory in his publications prior to the 1992 book, so his system has been subjected to speculation regarding its meaning and application without a conclusive reference source being available for determining the validity of dissenting positions. On the other hand, Deming (1994) claimed that “the 14 points of management” (p. 93), which he described in chapter two of his earlier book, *Out of the Crisis*, did “follow naturally as application of this knowledge, for transformation from the present style of Western management to one of optimization” (Deming, 1994, p.93). It can be concluded, therefore, that Deming’s management philosophy ultimately rests on his system of profound knowledge. In summary, uncertainty regarding the specific meaning and application of this system may lead to misinterpretation of Deming’s entire philosophy.

This research will follow two paths of inquiry. The first will explore the historical context for the system of profound knowledge and convert it into a scientifically grounded theory. Operational definitions of its elements will be developed. That theory will be derived from the concepts that historically were embedded in Walter A. Shewhart’s (1891-1967) thinking as expressed in his book, *The Economic Control of Quality of Manufactured Product* (Shewhart, 1931), and that later were embedded in Deming’s proposed system. The result of this first inquiry will be a coherent, scientifically rigorous theory upon which management practice may be applied.

The second path of inquiry for this research will be to validate the construct associated with the emerging theory. That mental model will support the pursuit of profound knowledge within the context of the strategic management of organizations by their executives. It will be based on the theory’s intellectual roots and will provide context for the four elements of Deming’s system. Ultimately, the perspective of executive management will be the principal focus of this dissertation’s research.

This research will engage an expert panel to provide a critique of the proposed theory and its supporting elements. The panel will evaluate whether the insights garnered from the investigation used to develop the new theory advance understanding of it and warrant further research to consider its role in EDM (EDM) and change management.

Expanded post-dissertation research related to this new theory will explore the decision processes and criteria associated with the strategic choices made by executive management. These decisions stimulate organizational transformation through planned strategic change initiatives in order to achieve the outcomes proposed from discovery of profound knowledge. This follow-up research will emphasize the factors that contribute to clarification of the practical meaning of an organization's data and how that meaning enhances the quality of executive decisions that are based on data and analyses. The hypothesis here is that executives who make decisions based on a clear understanding of the meaning of data related to their associated factors contribute to the increased performance capability of their organizations.

1.2 The Quality Contribution of the Executive Function

Henri Fayol, who lived from 1841 to 1925, wrote *General and Industrial Management* (Fayol, 1916), and it was the first book to prescribe a general theory of management. Fayol identified the continual improvement of quality as a critical function of executives and a responsibility that needed to be pursued constantly. He believed that executives must execute a "constant search for improvements that can be introduced into every sphere of activity. The search for improvement should be pursued unceasingly at all levels and throughout all parts of the business. The executive in charge should have an active and unrelenting intention to effect improvements (Fayol, 1916; also Brodie, 1962; Pearson, 1945; Wren, Bedeian, & Breeze, 2002).

More recently, in a study of the *Letters to Shareholders* ,written by the former General Electric Chief Executive Officer, John E. (Jack) Welch (1935-), he noted that the obligation of a chief executive is to deliver: "short-term profit and long-term organizational strength" (Watson, 2001, pp. 13-17), In his correspondence, Fayol previously had observed, "We know how technical capability is obtained, but it is difficult to say how administrative competence is obtained" (Wren, et al., 2002, p.21).

A long-term, continual pursuit of quality improvement in business requires a structured method for thinking about how to focus on this problem beyond subjective, ad hoc solutions. Fayol (1930) defined this approach as a sequential process of five activities which subsequently became the basic definition for a process of management—planning, organizing, commanding, coordinating, and controlling. Fayol's concept of management as a controller implied that it is essential that management receive feedback, analyze deviations, and make adjustments as appropriate. Fayol's concepts of continual improvement and control became essential elements in the development of quality as a scientific pursuit in the early 1900s.

1.3 Motivation for This Research

During an interview with Ira M. Millstein (1926-), the founder of the Global Corporate Governance Forum, he made the comment, "What industrial engineers must contribute [to improving the quality of corporate governance] are improved methods to support the making of executive decisions and development of an improved decision-making process, which together can assure the quality of future outcomes based on executive decisions. The methods of industrial engineering must be elevated from the production floor to the head office" (Watson with Millstein, 2009). This comment was echoed in a comment by Pekka Ala-Pietilä (1957-), former Chief Executive Officer of Nokia Mobile Phones, "The new frontier for quality improvement will be in the improvement of executive decisions. How can executives gain the knowledge required to make the best informed choices about their strategic direction? What is the best-practice process for making executive decisions that shape an organization's strategic direction?" (Watson with Ala-Pietilä, 2014) These expressed needs established the motivation for developing a structured, scientifically-based mental model that enables support of EDM based on the pursuit of profound knowledge to stimulate organizational transformation, so organizations become more effective, efficient, economical, and sustainable operations.

The post-dissertation phase of this research will conduct a rigorous inquiry into the scientific basis of EDM to extend the system of profound knowledge, formulating a comprehensive theory that may be used for improving the quality of executive decisions when formulating strategy, and therefore that research will facilitate achievement of organizational transformation.

Success in this post-dissertation phase of research first requires developing a sound theory of profound knowledge to enable successful practice of the new theory. Thus, the emphasis of the dissertation will be to develop a scientifically grounded theory of profound knowledge that later can be supported with practical and effective application methods.

1.4 Statement of Research Purpose

The purpose of this research is to understand the foundations of Deming's proposed system of profound knowledge and to extend it into a comprehensive new theory that can be used to support EDM and improve the quality of the strategic choices used to manage organizational transformation.

1.5 Problem Statement

Formalize the system of profound knowledge as postulated by Deming into a scientific theory for the pursuit of knowledge that supports objective development of strategic choices by executives for transforming the performance quality of their organizations.

1.6 Discussion of the Problem

Developing a problem statement for this inquiry presented a challenge because it involved a meta-problem that needs to be solved. Not every problem can be defined by a gap between a current state and a desired state of process performance. Some problems are far more complex and are associated with an amalgamation of multiple performance gaps.

EDM is a cognitive process that involves psychological considerations and describes a mental state of the decision maker that must remain flexible in order to respond effectively to the external shifts associated with situational dynamics imposed from the organization's environment. Exceptional performance in this circumstance requires insight into the impactful situation and the ability to make sense out of the various signals associated with it. Those signals provide inputs to the future potential state of performance which are needed to fulfill the evolution of the organization's purpose, which is the ultimate goal. Thus, the development of exceptional EDM requires application of a cross-disciplinary approach to the process of supporting the development of strategic choices regarding the organization's future direction. This process considers all issues raised by a multitude of disciplines inclusively and should not be confined to a myopic perspective. The cross-disciplinary approach integrates administrative behavior, social psychology, and behavioral economics (e.g., applying concepts that have evolved over the past half century. One of these concepts is bounded rationality theory developed by Herbert A. Simon (1997), who lived from 1916 to 2001. Sense-making and situational awareness were ideas developed by Karl E. Weick (1979), who was born in 1936. Furthermore, the dynamic capability concept of David J. Teece (2009), who was born in 1948, as well as the dualistic approach to thinking reflected in the System 1/System 2 model of thinking behavior that was proposed by Daniel Kahneman (2011), who was born in 1934. The psychology element in the system of profound knowledge was did not consider these and other related concepts and it actually was focused not so much on psychology as on motivating work.

The problem investigated in this dissertation will focus on the scope covered by Deming, rather than development of these additional thinking pathways. However, in the post-dissertation related to applications of this research regarding EDM, this restriction will be lifted and a more holistically based inquiry into the behavioral dynamics of the EDM process will be taken. This future emphasis will fulfill the motivational considerations that served as the basis for this dissertation.

Therefore, the problem statement for this inquiry has been formulated in a way that will permit its expansion in a post-dissertation phase associated with an inquiry into EDM and the related behavioral research questions that are raised.

1.7 Significance of This Study

This present study produces significant results in four outcomes, as described in the following sub-sections.

1.7.1 Investigation of the Intellectual Foundations of Quality

This study documents the evolution and intellectual foundations of quality thinking starting with its initial description by Shewhart and identifies the intellectual roots that subsequently influenced the creation of Japanese Total Quality Management (TQM) and modern Western quality methods.

1.7.2 Development of an Operational Definition for Profound Knowledge

This study establishes an operational definition for profound knowledge which had not been specified clearly by Deming. It also will clarifies the meaning of the four elements in his system of profound knowledge which he had not explained completely in his earlier discussions.

1.7.3 Reawaken an Academic Interest in Shewhart's Theories of Control and Prediction

This study lays the groundwork for a greater understanding and broader application of the writings of Shewhart. It will stimulate additional interest in addressing his proposed research agenda, which is only partially addressed in this initial investigation. Furthermore, it will position Shewhart's theories of control and prediction by demonstrating how a scientific grounding can be applied pragmatically to increase managerial control of organizational performance.

1.7.4 Establishing an Intellectual Foundation for a New Generation of Statistically Based Quality Improvement

Finally, this study will develop the intellectual foundation for a third generation in the application of statistically based quality improvement. In the first generation of his work, Shewhart focused on the pursuit of assignable cause variation through inquiry into the means of sampled data for tangible processes of production. His intention was to identify the assignable causes of variation that could be characterized statistically as being beyond the probability of the natural system of variation in the process data. Because calculations were made manually and there were many measurement errors that created problems, Shewhart developed his methods as far as the technology of his day made reasonably feasible. This initial work recognized that the statistical approach could identify special causes or activities that created divergent performance, assuming that deviating performance could be eliminated from routine work in order to achieve performance improvement.

Deming advanced this thinking during his development of the system of profound knowledge. He addressed the inherent variation in process performance, relying on methods for organizational theory that had developed in the half-century following Shewhart's studies. Deming's work shifted the focus from the process-level of tangible work to the organizational level that influences the degree of quality outcomes associated with that work. He therefore increased the scope of responsibility for quality performance from the worker level to the executive level.

When formulating his system of profound knowledge, Deming illustrated that inherent variability contributes substantially to preventing the sustainability of business success over time. Thus, the second generation of statistically based quality supplemented the statistical methods with a system-based perspective and deeper understanding of human nature. This provided a more rational platform for pursuit of a comprehensive approach for inquiry into the causal nature of process variation. However, Deming's system still remained focused on special causes of variation despite that the target of the associated analyses was expanded to include sources of human error as well as the physics of the process for manufacturing components and assembling them into products. Fundamentally, the system of profound knowledge permitted the expansion of quality methods into the domains of service, government, education, and healthcare because inquiries began to include intangible activities that contributed to special causes of variation. However, Deming's focus, like Shewhart's, was on the elimination of special causes of variation that create instability in process performance.

As a result of this dissertation research, the focus will be elevated from the process level to the system level of organizational performance. Although the system of profound knowledge identified an appreciation for systems as one of its structural components, the evolved theory associated with this new research will embrace systems thinking and define the executive role as being the achievement of organizational strength through the development of a resilient system of performance that comprehensively manages the set of common-cause variation. Having this enhanced capability will drive organizational capacity to attain the total performance of a business system.

The third generation of statistical thinking, as identified in this dissertation, will extend the foundation presented in the system of profound knowledge to formulate a more comprehensive scientific approach that will be called the theory of profound knowledge. The ultimate purpose of the associated mental model is to facilitate strategic organizational change—the conscious restructuring of an organization's purpose, policies, processes, infrastructure, and core competencies in order to achieve either a desired future state or an increased level of operational control over its performance outcomes. This mental model presumes that executives will make appropriate decisions regarding organizational resources so that a common, systemic goal can be achieved through coordinated, shared, and purposeful actions. These decisions are intended to deliver increased capabilities that extend the organization's resource effectiveness and efficiency, which mutually benefits all stakeholders. In other words, applying the elements associated with the theory of profound knowledge can be expected to attain far more transformative results for the organization than those associated with studies related to the variation of specific processes, as described in the first two generations of statistical thinking. Essentially, this expansion of Shewhart and Deming's work encompasses an organization's overall performance, rather than limiting the focus to its individual processes. This elevates the investigation of process performance from just the special causes of process variation to include the common-cause systems of variation, creating a more comprehensive perspective of organizational performance.

The extension of this study in the post-dissertation phase will provide a substantially increased contribution based on application of the scientifically grounded theory that will emerge. The follow-up research will identify components of strategic quality that belong uniquely within the executive function of organizations because they are core leadership responsibilities. Its findings will clarify the means by which the executive function can encourage and facilitate deployment of modern quality principles and methods as a strategy to improve an entire organization.

CHAPTER II

REVIEW OF LITERATURE: DEMING CHALLENGE—INTERPRETING A SYSTEM OF PROFOUND KNOWLEDGE

This chapter describes the development of the thinking process which Deming described as the system of profound knowledge and advances Deming's concept by presenting a research model for organizational transformation that will serve as a foundation for a derivative theory of profound knowledge.

2.1 Research Assumptions

The assumptions described in the following sections have been made while pursuing this research.

2.1.1 General Influences on Deming's Work

The citations in the books written by Shewhart and Deming clearly indicate that physicist Percy W. Bridgeman (1882-1961) significantly influenced the ideas of Shewhart and subsequently Deming, which makes sense given that both Shewhart and Deming received their doctoral degrees in the field of physics. Bridgeman's philosophical book, *The Logic of Modern Physics* (Bridgeman, 1927) was used by Shewhart as the opening quotation in his book, *Economic Control of Quality of Manufactured Product* (Shewhart, 1931). Bridgeman was influenced strongly by the theory of relativity and thinking processes (called thought experiments) proposed by Albert Einstein (1879-1955) in his book, *Physics and Reality* (Einstein, 1936), which changed the way scientists conducted experiments using mental models of reality. Central to Bridgeman's thinking was the idea that nature may be analyzed in terms of what philosopher Alfred North Whitehead (1861-1947) had called "events" in his book, *The Function of Reason* (Whitehead, 1929). Whitehead contended that a clearer understanding of the physical world occurs when the operational nature of the complex connectivity of physical reality is explained by a scientifically based mental model. The model aids in developing causal relationships among "actual entities" (Whitehead, 1929, p. 41) that concretely determine the "underlying reality" (Whitehead, 1929, p. 116). Shewhart also referred to Bridgeman's insightful claim.

> A situation like this merely means that those details which determine the future in terms of the past may lie so deep in the structure that at present we have no immediate experimental knowledge of them, and we may for the present be compelled to give a treatment [of them] from a statistical point of view based on considerations of probability. (Bridgeman, 1927, p. 116)

Thus, it can be assumed that the concepts associated with mental models, operational definitions, and using probability to understand potential future states were key contributors to Shewhart's thinking. Shewhart suggested that the actual entity concept of Whitehead should be the approach used to describe quality characteristics of manufactured products (Shewhart, 1931, p. 486). Additionally, Whitehead's process philosophy provided the intellectual cornerstone of systems engineering which emerged in the mid-twentieth century following World War II.

2.1.2 Scientific Methods and Scientific Inquiry

Shewhart demonstrated deep knowledge of the historical dialog regarding scientific methods and the evolving approach to scientific inquiry. Therefore, it seems likely that he developed his "theory of control" to address contemporary issues related to the pragmatic pursuit of scientific knowledge as it applies to the manufacturing environment of his day. Shewhart's interest was stimulated by an earlier essay by Charles Sanders Peirce (1839-1914), "How to Think Clearly," which originated a new generation of inquiry into the "meaning of meaning," and held implications for a multitude of academic disciplines (Peirce, 1878, pp. 286-302). This essay extended a philosophic argument regarding epistemological relationships between belief, justified belief, and justified true belief that initially had been proposed by William K. Clifford (1877) (1845-1879) and later countered by William James (1896) (1842-1910). The philosophy of American pragmatism flourished based on these intellectual seeds, becoming a dominant driver of modern business and also contributed to the formulation of the framework for Shewhart's theory of control.

2.1.3 Spectrum of Control

Furthermore, it is assumed that the structure of Shewhart's theory of control was motivated by a need to demonstrate how his concept of statistical control fit into the knowledge spectrum implied in the arguments defining the meaning of belief that were resident in rethinking of science during the prior century, and this stream of prior scientific thinking implicitly had formulated a mental model for describing progress in scientific discovery.

The concept of a mental model was conceived by Kenneth J. W. Craik (1943) (1914-1945). Craik postulated that the human mind forms models of reality based on observations in order to organize reality into a structural form that permits prediction of the occurrence of future events. The spectrum of control that Shewhart (1931) defined contained six levels beginning with a foundation representing the mental model of an aboriginal's naïve belief in the powers of mythical gods to affect life's experiences. The next two levels align with concepts of justified belief and justified true belief. The fourth and fifth levels represent Shewhart's application of Bridgeman's logic, identifying belief based on knowledge within boundary control conditions (statistical process control) and maximum control (which may be considered to be engineering process control in modern terms). The final level of this belief-oriented spectrum concludes with the purity of knowledge that is founded on the exact laws of science. These six levels describe how learning occurs with naïve belief gradually being converted into increasingly clearer and more logical expression during the pursuit of scientific inquiry (by the application if statistical quality control).

Learning evolves through scientific inquiry that investigates a series of research hypotheses through scientific experimentation and confirmation. Thus, the scientific method creates new knowledge about alternatives for action in processes and produces new understanding about reality. For Shewhart, this process of scientifically based inquiry generated pragmatic process knowledge about how to improve the quality of an organization's manufacturing system.

2.1.4 Scientific Method and Learning

Another research assumption is that the scientific method provides an adequate intellectual model for learning by applying a structured process of observation, reflection, analysis, and prediction. This early view of science was undergoing transformation at the time of Shewhart's work, and the writings of Thorvald Nicolai Thiele (1943) (1838-1910), John Dewey (1910) (1859-1952), and Bridgeman influenced ideas regarding observation, reflection, and analysis and prediction, respectively. Statistician Karl Pearson (1900), who lived from 1857 to 1936, had forecast this transformation in thinking in his book, *The Grammar of Science*, saying, "We ought first to notice that the use of the word belief in our language is changing: formerly it denoted something taken as definite and certain on the basis of some external authority; now it has grown rather to denote credit given to a statement on a more or less sufficient balancing of probabilities" (p. 59).

Harvard psychologist Chris Argyris (2000), who lived from 1923 to 2013, wrote an article that argued learning is a "reflection of how [people] think–that is the cognitive rules they use to design and implement their actions” (p. 5).

Throughout this dissertation, the term, “Bayesian moment,” will be used to describe the moment when transformative ideas become the foundation for making a decision. This is the point where a decision maker’s insight is used to interpret hindsight (historical data) in order to develop foresight (plans for change), guiding decisions related to the future (strategic direction). Argyris (2000) emphasized that a specific focus was required to ensure successful strategic decisions, described as “What it takes to make the way that managers and employees reason about their behavioral focus of organizational learning and continual improvement programs” (p. 6). Questions such as “Why do executives decide to execute based on what happens in the Bayesian moment?” and “What role does profound knowledge perform in this decision process?” emerge as key research concerns.

It is assumed that the learning theory developed by Argyris is applicable to this Bayesian moment, which describes the decision-making process that converts knowledge of historical performance into decisions that influence future performance. Executive decision making (EDM) occurs in the insight portion of the Bayesian moment (see Figure 1), where alternative choices are considered for future actions based on the current state of information gained from pursuing profound knowledge. This model is developed further later in this chapter. During the Bayesian moment, the decision makers achieve clarity of sight if they are able to obtain profound knowledge that aids in their decision-making process. Achieving such clarity describes a state of mindfulness that combines sense-making and situational awareness, generated from the confluence of hindsight and insight.

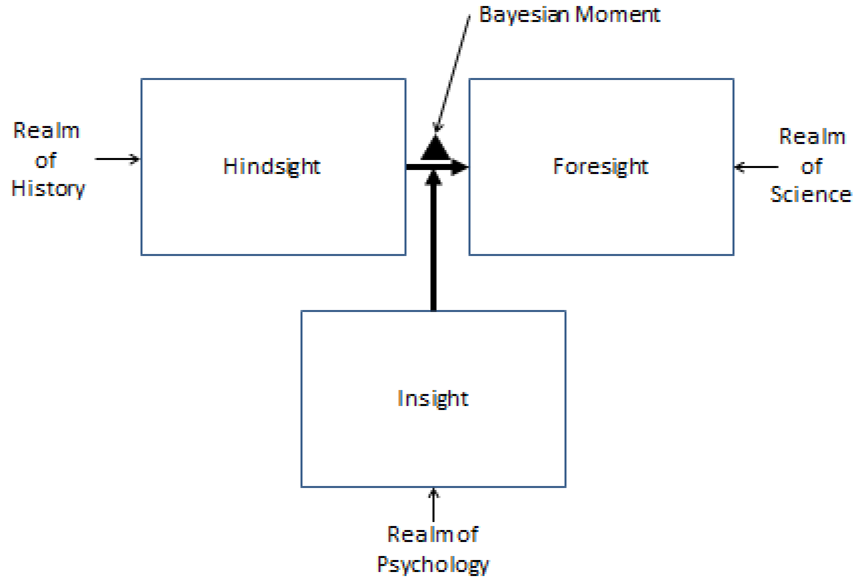

FIGURE 1: Bayesian Moment Mental Model of Human Inquiry in Decision Making

Executive mindfulness regarding the decision-making process executed during the Bayesian moment is an imperative for achieving strategic decisions that will define the future direction of the organization as it transforms from its current and historical approach to fulfilling its purpose and subsequently to enhancing the way it chooses to embrace the challenges of its future state. Executives can be taught what Argyris (2000) calls "tough reasoning" that leads to effectiveness:

> People can be taught how to recognize the reasoning that they use when they design and implement their actions. They can begin to identify the inconsistencies between their espoused and actual theories of action. They can face up to the fact that they unconsciously design and implement actions that they do not intend. Finally, people can learn what individuals and groups do to create organizational defenses and how these defenses contribute to an organization's problems (pp. 45-46).

Argyris (2000) points out that "theory in use" or the actions that people actually take based on objective observations and the decision rules that are derived from their actions may be inconsistent with the theory that they believe, describe in language, or act upon–a schizophrenia between the way that they think they act and the way that they actually act (p. 28). Executives need to learn how to manage this schizophrenia.

2.1.5 Shewhart's Influence on Deming's Work

Another fundamental assumption of this research is based on the nature of the personal relationship between Shewhart and Deming. It appears that Deming named his last book, *The New Economics*, to recognize and extend the contributions that Shewhart presented in the *Economics of Control of Quality of Manufactured Product*. This assumption is based on some specific observations. First, the relationship between Deming and Shewhart began when Deming studied under Shewhart at Bell Laboratories; they maintained a close relationship during the period when Shewhart produced his magnum opus. Deming clearly learned as Shewhart advanced his thinking during those years. Furthermore, when Deming worked at the United States Department of Agriculture, he invited Shewhart to deliver a series of lectures in the late 1930s. Deming later edited those lectures to create Shewhart's second book, *Statistical Method From the Viewpoint of Quality Control* (Shewhart, 1939). The third and most convincing reason is the body of letters that exists as a record of life-long correspondence between Deming and Shewhart, which supports the assumption that Deming continued to consider Shewhart to be his mentor (Blankenship and Petersen, 1999, pp. 454-467). In fact, Deming not only was a student of and editor for Shewhart, but he also became a dedicated devotee, promoter, and apologist for Shewhart's ideas (Deming, 1967, pp. 39-40).

2.1.6 Foundation for Deming's Proposed System of Profound Knowledge: Shewhart's Research Agenda

Another related assumption is that as Deming aged he reflected on his life's work and how to complete his goals. His last book consolidated his teachings into a more comprehensive approach and made corrections to others' misperceptions regarding his work. In fact, Deming extended his reflections to assure that his tightly coupled relationship with the thinking of Shewhart would be evident. This is important because it becomes apparent that Deming came to understand the importance of the research agenda that had been proposed by Shewhart but which Deming had not addressed as of 1992. Specifically, this research assumes that the system of profound knowledge attempted to provide structure by characterizing the loosely complied list of research topics which was included as Appendix 3 of Shewhart's 1931 book.

Later in this dissertation, these affinities will be shown in a table that illustrates how the areas that Shewhart had recommended for further consideration can be mapped into the four categories that Deming proposed for his system of profound knowledge. These observed connections appear to be well beyond the realm of mere coincidence. Deming's unique contribution was to identify these four components of profound knowledge and to link them (albeit loosely) with concepts of executive responsibility for transformation through the cycle of learning by scientific discovery. (It's worth noting that Deming made a somewhat superficial name change related to the plan, do, check, act cycle (Japanese PDCA Control Cycle) by substituting the word "study" in place of "check" (Deming, 1994, p. 132), turning it into PDSA, to highlight that he considered his methodology to be a learning process.

2.1.7 Shortcomings in Deming's Proposed System of Profound Knowledge

Because Shewhart had passed away almost a quarter century before Deming wrote his last book, there was no opportunity for Deming to inquire about the objectives of his mentor's research recommendations or the meaning implied by those recommendations. Deming was 92 at the time he published *The New Economics*, and his writing in that book is sometimes rambling and disjointed. Additionally, Deming often was confused about the nature of the philosophical content proposed in Shewhart's ideas, and this caused him great difficulty in understanding some of the broader and more abstract concepts, as described in Deming's comment in *The New Economics* regarding the ideas expressed by Clarence I. Lewis (1883-1964) in his book *Mind and the World Order* (Deming, 1994, p. 101; Lewis, 1929). Deming also seemed not to have sufficient intellectual energy or curiosity to investigate the deeper meanings behind the set of categories that he identified as a system of profound knowledge, so he relied on his personal knowledge and acquaintances to describe and illustrate these four components. These assumptions are supported by the fact that Deming did not provide any footnotes or specific references as a foundation for the precursors that led to the four elements in his system. Perhaps his approach to the system of profound knowledge would have evolved differently if he had done the research into quality that had been recommended by Shewhart or if Deming had described the intellectual developments that occurred when he realized these relationships and published the system's description for the first time.

2.2 Definitions of Terms Related to Shewhart's Theory of Control

One significant oversight in Deming's book, *The New Economics,* was his failure to define the key terms related to his system of profound knowledge operationally. Bridgeman (1927) advised, "…the true meaning of a term is defined by observing what a man does with it, not by what he says about it" (p. 7). This is called an operational definition.

In this section of the dissertation, the terms originally introduced by Shewhart are defined to aid in understanding their evolution in the thinking of Deming. Shewhart's *Economic Control of Quality of Manufactured Product* might have been better if it had been named "The Theory of Control" because over half of the text describes quality, and variation, but relatively few pages deal with economics. Four terms whose original meaning was assigned by Shewhart were reinterpreted subsequently by Deming, but operational definitions of them in their original context are necessary to grasp completely the foundations of Deming's system and to appreciate fully the contribution of Shewhart.

2.2.1 Quality

Since the time of Aristotle [ca. 300 BCE], there has been a general tendency to conceive of quality as indicating the goodness of an object. In general, the quality of a thing is perceived as that which is inherent in it; so it is not possible to alter this characteristic quality without altering the thing itself. Upon deeper consideration, it becomes evident that in almost every case the conceptual "something" is really a group of conceptualizations that are more elementary in form. The minimum number of characteristics required to define an object can be called its qualities. For example, William Stanley Jevons (1875), who lived from 1835 to 1882, said, "The mind learns to regard each object as an aggregate of qualities and acquires the power of dwelling at will upon one or other of those qualities to the exclusion of the rest" (p. 25). Shewhart quoted the author of the first book on quality control by inspection, George S. Radford (1922) who lived from 1881 to 1956, and had written the following text:

> The term "quality," as applied to products turned out by industry, means the characteristic or group or combination of characteristics which distinguishes one article from another, or the goods of one manufacturer from those of his competitors, or one grade of product from a certain factory from another grade turned out by the same factory. (p. 4)

"In this sense a thing has qualities and not a quality" (Shewhart, 1931, p. 39). Shewhart (1931) suggested the following:

> …it is necessary for us to think of a quality characteristic as an entity in the sense adopted by Whitehead if it is to be general enough to be of use in the many practical problems that arise in the interpretation of a sample (p. 486).

Whitehead described his concept of the "actual entity" in a philosophical treatise, *Process and Reality* (Whitehead, 1985), which he delivered as the 1929 Gifford Lecture. He treated an "actual entity" as a reality which is the outcome of a process or activity. Thus, quality should be considered as both the "real" content (e.g., a product or service) that is delivered through the execution of an actual process.

In this dissertation, the term quality is operationalized as the persistent pursuit of goodness coupled tightly with the relentless avoidance of badness. These judgments of an actual entity or the actual activity that produces it should be made by the customer of the deliverable. (Cole and Matsumiya, 2007, pp.77-93)

2.2.2 Control

Shewhart (1931) wrote, "The problem [of control] is: how much may the quality of a product vary and yet be controlled? In other words, how much variation should we leave to chance?" (p. 3)

> …a phenomenon will be said to be controlled when, through the use of past experience, we can predict, at least within limits, how the phenomenon may be expected to vary in the future. Here it is understood that predictive within limits means that we can state, at least approximately, the probability that the observed phenomenon will fall within the given limits (Shewhart, 1931, p. 6).

2.2.3 Cause

This term is defined as follows:

> As human beings, we want a cause for everything, but nothing is more elusive than this thing we call a cause.... All that we can do is find certain practical rules or relationships among the things which we observe. In doing this, we introduce a lot of terms which we

> cannot explain in the fundamental sense, but which we use to great advantage as for, example, mass, energy, electron, and so on. Under these conditions we go ahead undaunted and introduce 'theories' as to how these things are related, even though we do not know what these things are that we talk about…. Nevertheless, when we apply control theory, as we do in this book, it is just as easy to get a 'feeling' for what we mean by cause in a specific case as it is to get a feeling for what we mean by light when we talk about it (Shewhart, 1931, p. 131).

2.2.4 Chance Causes

Shewhart (1931) identified and described a particular category of causes whereby the problem of "formulation of a scientific basis for prediction, taking in to account the element of chance, where for the purpose of our discussion, any unknown cause of a phenomenon will be termed a chance cause"(p. 7).

2.2.5 Variable System of Chance Causes

Process performance may be quantified in any measurable system by the statistical analysis of data sources. Variation is identifiable in the performance data for the process with respect to its critical quality characteristics. Such measures accumulate over time to define the causal structure of a process. "Constant systems of chance cause give rise to frequency distributions are often called statistical laws" (Shewhart, 1931, p. 133). Process outcome data which demonstrate such performance are predictable because only random variation affects their resultant outcomes. However, whenever a variable system of chance causes" occurs, then predictable reasons and mechanisms for "the causes of… fluctuations, are, for the most part unknown. The general belief is, however, that variations of this character show distinct trends and possibly cyclic movements– the existence of either will rule out the constancy of the cause system" (Shewhart, 1931, p. 132). To achieve control in an outcome, it is necessary to assure that only chance (e.g., random) variation exists in the process.

2.2.6 Assignable Cause Variation

Uncontrolled processes are unstable processes with irregular and unpredictable outcomes due to the presence of special causes of variation. These special causes can be assigned to identify the source of the variation.

> The practical situation, however, is that in the majority of cases there are unknown causes of variability in the quality of a product which do not belong to a constant system. This fact was discovered very early in the development of control methods, and these causes were called assignable. The question naturally arose as to whether it was possible, in general, to find and eliminate such causes (Shewhart, 1931, p. 14).

2.2.7 Unassignable Cause Variation

This is a synonym that Shewhart derived for a chance cause of variation—variation whose mechanism cannot be otherwise explained. A controllable process is stable and exhibits predictable regularity because only chance causes infrequently affect its outcome performance, and the same process mechanisms have a common effect on the process in an equally random fashion over time. The existence of only such variation implies process stability, and this permits reliable prediction of future outcomes within limits as Shewhart proposed. Unassignable causes of variation represent the collection of unknown influences on process performance which cannot be identified separately but which are included in the ordinary variation of the process due to the nature of its components design and execution.

Shewhart defined three logical postulates as a basis for his theory of control and specified them at the beginning of his discourse on control, as follows:

“Postulate 1–All chance systems of causes are not alike in the sense that they enable us to predict the future in terms of the past" (Shewhart, 1931, p. 8).

"Postulate 2–Constant systems of chance causes do exist in nature" (Shewhart, 1931, p. 12).

"Postulate 3–Assignable causes of variation may be found and eliminated" (Shewhart, 1931, p. 14).

Shewhart (1931) concluded, "Hence, to secure control, the manufacturer must seek to find and eliminate assignable causes. In practice, however, he has the difficulty of judging from an observed set of data whether or not assignable causes are present" (p. 14). Therefore, Shewhart developed a theory of control that classified the degree or level to which control is achievable based on the ability to isolate and identify these assignable causes of variation within a process.

2.3 Shewhart's Theory of Control as the Catalyst for an Inquiry Into Profound Knowledge

Shewhart's masterpiece, *The Economic Control of Quality of Manufactured Product*, actually defined a theory of manufacturing control based on his methods for analyzing data within boundary limits, using statistical process control (SPC). Most studies of Shewhart's work focus on his contribution to the development of SPC methodology and the Shewhart Cycle and have lost the significance of his contribution to development of a scientifically based theory of control. He constructed his theory based on study and understanding of the scientific method, statistics, probability theory, pragmatic philosophy, and production processes. Shewhart's (1939) idea of control centered on the use of SPC charts (process behavior charts) and a "dynamic scientific process for acquiring knowledge" (pp. 44-46), which later was named the Shewhart Cycle, to improve future quality of manufactured products. Thus, Shewhart's theory of control assured what Deming later called "constancy of purpose" in manufacturing processes based on the level of control that is achievable in a particular situation. These terms require definition.

2.3.1 Constancy of Purpose

This term was introduced by Deming (1985) in *Out of the Crisis*; however, it refers back to the purpose of control mechanisms, which is to develop a predictable state of future performance. Constancy of purpose is the long-term, continual pursuit of a learning process by which a predictable state of stability (in control) of work processes may be achieved (Deming, 1985, p. 24).

2.3.2 Levels of Control

This tern describes the level of stability or maturity which a process has achieved in its progress toward improved performance. Maturity is attained by applying Shewhart's Cycle of continual improvement. Shewhart (1931) identified six levels or stages of control to describe the relationship between a theory of control and exact science based on "the development of ways and means of making use of past experience" (p. 352).

Shewhart's (1931) scheme can be reframed to describe the six levels of control that may be observed in a process of learning for the development of knowledge, as shown below:

Level 1—"Belief that the future cannot be predicted in terms of the past" (p. 352).

Level 2—"Belief that the future is pre-ordained" (p. 352).

Level 3—"Inefficient use of past experience in the sense that experiences are not systematized into [predictable] laws [according to the method of science]" (p. 353).

Level 4—"Statistical process control methods are applied to a real world stream of process performance data to assure that it is able to achieve 'control within limits'" (p. 353).

Level 5—"Engineering process control automates the SPC through the use of decision criteria for quality and feedback loops to control the process within limits to achieve 'maximum control'–a state where only ’chance fluctuations in a phenomenon are produced by a constant system of a large number of chance causes in which no cause produces a dominating effect’” (p. 353).

Level 6—“Laws of science–Knowledge of all laws of nature–exact science” (p. 353).

This taxonomy for the levels of control and its derivation from the progressive works of previous researchers who investigated quality-related subjects is worthy of more attention. So, in Chapter III, the scientific debate that led to this theory of control will be described.

However, at the time of Shewhart’s research, the topics proposed by Deming as a system of profound knowledge were still in-progress conversations and had not reached the stage of development where they had become accepted as theories by their respective academic communities.

Thus, Shewhart’s contributions need to be interpreted in the context of the contemporary state of the evolving thinking that existed during his time and from the perspective that this level of advancement provided him for developing his theory of control. It was from these roots that Shewhart contributed to advance quality thinking. Shewhart made an incomplete contribution in his theory of control because he developed a categorical scheme but failed to develop a full mental model to display the operating relationships among the components of his theory. Also, although Shewhart did an admirable job in citing references, he failed to link his theory of control to contemporary discussions about the application of emerging scientific thought and methods and their particular relationships to developing a true science of quality, which ultimately emerged as an outcome of this control scheme.

The relationship of Shewhart’s proposed research focus areas to Deming’s four categories of profound knowledge is illustrated in the tabular version of an affinity analysis aligning these factors as shown in Table 1.

Deming's Four Categories Aligned with Shewhart's Proposed Research Directions	
Appreciation of a System	Wesley C. Mitchell, *Business Cycles* (New York: Bureau of Economic Research, 1927) Arthur E. Haas, *Introduction to Theoretical Physics* (London: Constable, 1928) Alfred N. Whitehead, *Process and Reality* (New York: Macmillan, 1929) C. Dampier Wetham, *A History of Science* (New York: Macmillan, 1930) Wallace B. Donham, *Business Adrift* (Cambridge: Harvard, 1931)
Knowledge of Variation	Thorvald N. Thiele, *Theory of Observations* (London: Britannica, 1903) John Maynard Keynes, *A Treatise on Probability* (New York: Macmillan, 1921) Ronald A. Fisher, *Statistical Methods for Research Workers* (London: 1925) Ethel M. Elderton, *Frequency Curves and Correlation* (London: Layton, 1928) Alfred de Forest Palmer, *The Theory of Measurements* (New York: McGraw-Hill, 1930)
Theory of Knowledge	William S. Jevons, *The Principles of Science* (London: Macmillan 1924) Bertrand Russell, *The Analysis of Matter* (New York: Harcourt Brace, 1927) Charles D. Broad, *Scientific Thought* (New York: Harcourt Brace, 1927) Percy W. Bridgeman, *The Logic of Modern Physics* (New York, Macmillan, 1927) Arthur S. Eddington, *The Nature of the Physical World* (New York,

	Macmillan, 1928) John Neville Keynes, *Formal Logic* (London: Macmillan, 1928) Alfred N. Whitehead, *The Function of Reason* (Princeton: Princeton University, 1929) J. Henri Poincare, *Foundations of Science* (New York: Science Press, 1929) John Dewey, *Quest for Certainty* (New York: Balch, 1929)
Psychology	William James, *The Principles of Psychology* (New York: Holt, 1890) Bertrand Russell, *The Analysis of Mind* (London: Allen and Unwin, 1922) Edward L. Thorndike, *Human Learning* (New York, Century, 1931).

TABLE 1: Intellectual Affinities Between the Content of Shewhart's Proposed Research and the Categories of the System of Profound Knowledge

Thus, in 1931, Shewhart left unfinished work in the form of his recommendations for future research. There appears to be no evidence of subsequent research into this line of thinking in developments of quality methods in the Americas, Europe, or Japan. Although he did not pursue that research, he specified a proposed research plan in Appendix 3 of his book (Shewhart, 1931, pp. 473-491).

Shewhart prepared a potential research pathway to extend statistical thinking to enterprise-level strategic decisions, but he did not investigate that pathway or demonstrate how to use control charts to support executive decisions. It was not until Deming reached the end of his career that this extension of Shewhart's thinking process was addressed somewhat—although not definitively. To understand properly the complete implications of Shewhart's ideas, an examination of Deming's derivative work in applying Shewhart's theory of control as a way to assist executives in the job of transforming organizations is necessary. How did Deming interpret

Shewhart's control theory and how did his understanding develop over time to stimulate the creation of his system of profound knowledge?

2.4 The Symbiotic Relationship Between Shewhart and Deming

If the intellectual roots for Deming's system of profound knowledge are not found in Shewhart's writings, then exactly where did they originate? Which of Shewhart's intellectual ideas served as a cornerstone for Deming's mental model? The proposition here is that Deming's (1994) book, *The New Economics,* was the final public statement in what could be called a lifelong thought experiment between Shewhart and Deming to discover the best way for thinking about matters related to quality and the method for its improvement. If this is true, then what was the intellectual pathway for the development of this transformative knowledge? The inquiry to answer these questions logically begins with Shewhart and developing an understanding of his work focus at the time his ideas originated.

2.4.1 Quality by Inspection

Shewhart's operational quality problem was grounded in the reality of problems in the telecommunications industry as it existed during his work. Frederick W. Taylor (1911) who lived from 1856 to 1915 and had established that work is measured in terms of the physical actions of workers and that tangible outcomes of that work could be observed, inspected, and analyzed to determine if there was compliance to quality. One of the outcomes of Taylor's approach was establishment of factory inspection departments to perform this checking function independently from management and the workers, relying on objective judgment that was not influenced by either of those parties. This organizational function expanded rapidly from its early beginnings in the mid-1880s and was adapted by Bell Labs in 1924 to form an Inspection Engineering Department, which developed its systematic approach to quality management (Fagan, 1976, p. 869). Shewhart was influenced directly by Radford (1922), whose emphasis was placed on defining the structure that is required to assure quality in the final product through a process of inspection. Shewhart (1931) did not support this system, emphasizing that quality by inspection was not economically viable, and he dedicated the first chapter of his book to explaining his position (pp. 3-7).

2.4.2 Application of Quality

Shewhart's initial thinking about the application of quality was published in a series of six articles that appeared in the *Bell Systems Technical Journal* between 1924 and 1929. These articles were the precursors to the development of the content and logical framework, and their publication sequence provides insight into Shewhart's orderly mind. This series was initiated prior to the beginning of his relationship with Deming, which commenced in 1927. The topics are covered in the chronological order in which they were developed and included the ideas described in the following sub-sections.

2.4.2.1 Universal law of error. Shewhart (1924) began the series by discussing the question, "Is there a universal law of errors?" He commented that the typical quality assurance methods set out to "control the causes of variation so that the resultant deviations of the observations from their arithmetic mean are small in comparison" (p. 43). The use of the mean of a series of observations to represent scientific findings had been a common practice at that time, and Shewhart's idea was an extension of the earlier scientific dialogs on measurement error of Thiele (1903) and Albert de Forest Palmer (1912), who lived from 1869 to 1940. Shewhart's (1924) ideas were derived from the statistical work of Pearson (1900) and Fisher (1925), who lived from 1890 to 1962, addressing the issue of not having normally distributed data available from measurements. After observing numerous data observations, Shewhart (1924) had noted that if "the causes [of variation in the data] are such as to be technically termed random, [then] we can answer all practical questions with a far greater precision than we can if the causes are not random" (p. 53).

This reflection led to his question, “Can we ever expect to find a normal distribution in nature?” (Shewhart, 1924, p. 60). He replied, “The answer is affirmative. If the resultant effect of the independent causes is proportional to their number, the distribution rapidly approaches normality as the number of causes is increased” (Shewhart, 1924, p. 60). Shewhart (1924) further demonstrated that, the overall effect of the sampling distribution error is “an exceptionally close approximation to the normal law” because the laws associated with sampling logic are drawn from the binomial distribution which approximates the normal distribution with large sample sizes. Thus, the range of errors introduced in a measurement itself is large compared to this concern about the sampling error (p. 60).

2.4.2.2 Measurement issues and their implications. Shewhart then published three more papers in the *Bell System Technical Journal* in 1926. In the first article (Shewhart, 1926), he addressed the quality data issue of “error correction” to determine if a production lot meets its specified quality characteristics, observing that “every measurement is subject to error” and adding

> …a manufacturer must constantly make measurements… in an effort to control his production processes and to measure the quality of his finished product in terms of certain of its characteristics, but, before he can safely determine the significance of observed differences in the production process or in the quality of his product as given by these measurements, he must make allowance for errors of measurement; i.e., for the fact that the observed differences may be larger or smaller than the true differences. To make such allowances for errors of measurement of any characteristic, to find out what the true magnitude of the characteristic most probably is, to find out, as it were, what a thing most probably is from what it appears to be, presents an endless chain of interesting questions to be solved. Three important types of problems arise in engineering practice...
>
> 1. Error correction of data taken to show the quality of a particular lot.

2. Error correction of data taken periodically to detect significant changes in quality of product.

3. Error correction of data taken to relate observed deviations in the quality of product to some particular cause. (pp. 11-26)

Shewhart also addressed the first two types of problems, and he introduced the cost of inspection as an analysis parameter to be evaluated. He considered his analysis as being performed within set boundaries defined by the population average plus or minus three standard deviations. Then he observed that when "the presence of errors of measurement increases the separation of these limits… our precision of detecting trend or cyclic fluctuation is thereby decreased" (Shewhart, 1926, p. 23.)

Shewhart started the second paper that year by asserting that analysis begins with an assumption about what he called "the customary error theory." He proposed that a data distribution is normal, and then it will attempt to "see how far customary error theory carries us, see where it breaks down, see why it breaks down, and then avail ourselves of the new theory–a powerful tool of great value because it makes possible for the first time the solution of many practical problems" (p. 310). He noted the issue that "in practice we don't know the root mean square errors [of the population], we know the root mean square or standard deviations [of the sample]" (Shewhart, 1926, p. 311). "These values of the ratio are not normally distributed" (Shewhart, 1926, p. 312).

Pearson (1900) had developed an understanding that the behavior of the sampling distribution approaches normality when the sample size is greater than 25, (pp. 157-175) and Shewhart coupled this knowledge with the use of the Student's t-distribution to estimate the standard deviation rather than using the normal distribution and Fisher's method of least squares for his analysis (Stigler, 1978, pp. 239-265). The examples he used to illustrate his point all had a sample size that was less than 25 and demonstrated the validity of his recommended move toward small samples for control charts (Stigler, 1978, pp. 316-318).

Next Shewhart (1926) turned to the implications of these measurement lessons to develop the control chart and set the context for the application of his control theory based on the concept of assignable cause variation, as follows:

> Irrespective of the care taken in defining the production procedure, the manufacturer realizes that he cannot make all units of a given kind of product identical. This is equivalent to assuming the existence of non-assignable causes of variation in quality of product. Of course, random fluctuations in such factors as humidity, temperature, wear and tear of machinery and the psychological and physiological conditions of those individuals engaged in carrying out the manufacturing procedure may give rise to some of these apparently uncontrollable variations. Knowing this, the manufacturer contents himself with trying to produce a product which is uniform and controlled–one which does not vary from one period to another by more than an amount which may be accounted for by a system of chance or non-assignable causes producing variations independent of time (p. 593).

Shewhart focused the application of the quality control chart on detecting the causes of variation that are assignable. “The reason for trying to find assignable causes is obvious–it is only through the control of such factors that we are able to improve the product without changing the whole manufacturing process” (Shewhart, 1926, p. 593). He then raised a practical problem that is faced by manufacturers, asking

> When do the observed differences between the product for one period and that for another indicate lack of control due to assignable causes, and when, on the other hand, do the differences in quality of manufactured product observed from one period to another indicate only fortuitous, chance, or random effects which we cannot reasonably hope to

> control without radically changing the whole manufacturing process (Shewhart, 1926, p. 594)?

Thus, the purpose of the control chart is to provide a "method of differentiating the effects of assignable from those of non-assignable causes" (Shewhart, 1926, p. 596). Shewhart then addressed a series of problems which must be considered in designing a control chart—problems with specifications, estimations, distributions, as well as the fit between the observed and theoretical distributions where the data are grouped according to rational sub-groups within which manufacturing production performance is expected to be uniform. This paper showed how statistical control charts could be used to detect assignable causes of variation which result in lack of control of product quality characteristics.

2.4.2.3 Quality control. The next paper extended Shewhart's (1927) discussion to the subject of quality control. He clarified the application of control charts to the objective of attainment of control over the quality of manufactured product, as follows:

> It should be noted that from a statistical standpoint the control charts are based on a priori reasoning. The type of cause system specified by the engineer is taken as a standard a priori system which is accepted as an ideal which the manufacturer hopes to maintain. The control chart thus makes it possible to differentiate between deviations in quality which can reasonably be accounted for on the basis of sampling and those deviations which cannot be accounted for. It will have been noted that the limits are a function of the size of the sample n. The question is therefore often raised: 'How large a sample shall be chosen?' So long as we are willing to risk our engineering judgment that the system of causes is controlled, we need take no samples. In those cases where customary practice calls for the inspection of a certain number of units of product for reasons other than control, these data may be used in the manner outlined above to indicate the degree of

control (p. 735).

Shewhart concluded this paper by observing that most production processes require testing of the product to assure its quality is achieved at one stage of production before it is advanced to the next stage. He recommended that this data be obtained using a control chart to identify the presence of assignable causes of variation so they might be eliminated at an early stage of production which leads to the lowest cost of production. Shewhart's closing observation introduced the subject of the final paper in this series (Shewhart, 1931, p. 418).

2.4.2.4 Economic aspects of quality control. Shewhart focused on the economic aspects of quality control in an article (Shewhart, 1929) which evolved directly into the third chapter of his 1931 book. He used the same words to establish the linkage to the theory of control and in both texts. writing "It seems reasonable to believe that there is an objective state of control, making possible the prediction of quality within limits even though the causes of variability are unknown" (Shewhart, 1929, p. 389).

Based on the content of this series of six papers, it is clear that they collectively laid a foundation for Shewhart's text, *Economic Control of Quality of Manufactured Product*. How did this book link Shewhart's theory of control and Deming's development of his system of profound knowledge?

2.4.3 Achieving a State of Control Through Causal System Analysis

In that final article, Shewhart advocated for achieving a state of quality through causal system inquiry that is directed by using applied probability theory instead of relying on inspection-based quality. He dedicated a majority of his principal work to the development of a theory of control that served as an intellectual foundation, ultimately evolving through a symbiotic relationship with Deming into the system of profound knowledge (Shewhart, 1931, pp. 275-424).

In retrospect, it is clear that Deming identified several of the elements in his system from Shewhart's first book, including ideas that scientific knowledge is gained through pursuing identification and elimination of assignable causes of variation from work processes (Shewhart, 1931, p. 14). This study of causality occurs through the process of investigating the relationship associated with variability that exists within and between rational sub-groups of data generated by a process (Shewhart, 1931, pp. 299, 304-313, 409-412). It is essential to measure and sample the data properly paying particular attention to randomness, representation of rational sub-groups, and sample size (Shewhart, 1931, pp. 405-406, 409-414).

The discussion of psychology was a new subject of interest for Shewhart, and it first appeared in his final book, *The Economic Control of Quality of Manufactured Product*, (Shewhart, 1931), but had not been evident in his earlier papers. What did Shewhart have to say about psychology? Although Shewhart cited several contemporary texts as references that were related to psychology (Broad, 1927; James, 1890; Russell, 1922; Thorndike, 1931; Whitehead, 1929), he also made specific comments about the role of human choice on decision making in the application of the scientific method, as follows:

> It will be noted that the application of the formal scientific method in discovery involves a human choice at every step. For example, in the discovery of a functional or statistical relationship the following choices must be made:
>
> 1. Choice of data.
>
> 2. Choice of functional form.
>
> 3. Choice of number of parameters, at least in certain cases.
>
> 4. Choice of method of estimating parameters.
>
> To a certain extent this field of choice is kind of a methodological No-Man's Land

(Shewhart, 1931, p. 485).

In the preamble to Shewhart's discussion of his theory of control, he described his motivation for this inquiry as a "development of better ways and means of making use of past experience" (Shewhart, 1931, p. 352). Thoroughly analyzing the total set of conditions affecting process performance, including the human conditions, is important to achieving effective control of production systems.

> The statistical nature of things and of relationships or natural laws puts in the foreground this concept of distribution of effects of a constant system of chance causes. For this reason, it is important to divide all data into rational subgroups in the sense that the data belonging to a group are supposed to have come from a constant system of chance causes (e.g., [within such groups there can be] no observable changes in the physical or psychological factors that could change the state of production) (Shewhart, 1931, p. 418).

From these concepts, Shewhart established his idea, which became known as the Shewhart Cycle, and stimulated Deming's thinking process that nurtured several elements of his system of profound knowledge.

2.4.4 Data Management

Deming prepared a manuscript that addressed the subject of data management and the need to adjust sampled data in 1938, which was published later formally (Deming, 1943). He prepared this set of notes based on his "appreciation of the powerful stimulus of Shewhart's contributions to statistical procedures and the philosophy of science." The emphasis was on applying "a method of adjustment as a way at arriving at a figure that can be used for a given purpose–in other words for action" (Deming, 1943, p. iii). Deming (1943) said, "The object of taking data is to provide a basis for action" (p. iii).

Deming (1943) also commented, as follows:

> The measurement provides a basis for the action. If the measurement is wrong by so great an amount that the (object) is unfit for the purpose intended when it arrives, then the figure has led us to the wrong action. You might repeat the operation of measurement…. Whatever the exactness required, the problem is fundamentally the same. One takes a measurement–that is, one carries out an operation–and thus gets a certain result (a number) and writes it down. Why should he repeat the operation? The answer may be contained in one or both of two statements: (a) to get a better value for the purpose intended, by adjusting the observations; (b) to gain some assurance that he is following the procedure intended. The latter is often more important, though also more difficult. Methods of adjustment help us in both questions…. The object of taking data is to provide a basis for action, and an adjusted value is a derived number that can be used for the purpose intended, if it is possible to be had from the data presented for adjustment. The principle of least squares provides a method for getting an adjusted value (p. 2).

Deming (1943) concluded that "measurement or an adjusted value is a prediction in the sense that the number that we are going to use for the [measure] is about what we should expect anyone else to get if he were to measure [it]" (p. 3). However, Deming (1943) warned that: "a point is never to be excluded on statistical grounds alone" (p. 171). The practice of a rejection of data based on statistical analysis must be met with caution. Deming (1943) suggested that the use of Shewhart's control charts provided a good basis for prediction of data validity, saying,

> The purpose of drawing an error band or confidence band is to invoke statistical aid in detecting and in detecting spurious conditions in the data, or, more precisely, in the experimental conditions that gave rise to the data. A point that lies outside an error band of width two or three standard errors should be investigated; but it is to be discarded, and

the curve refitted, only if investigation discloses anomalous experimental conditions at that point. Whether one uses a band of width two standard errors or three standard errors is a matter that can be decided only by personal preference and experience in a particular line of work. The wider the band, the fewer the points outside it and on this criterion the less likely one is to look for experimental difficulties. On the other hand, if the band is too narrow, one will look for experimental difficulties too often–that is, he will be looking for trouble too often when there is no trouble (p. 171).

2.4.5 Theory of Prediction

The next step in this dialog between Shewhart and Deming was the development of what could be called a "theory of prediction" by Shewhart with publication in his second book, *Statistical Method From the Viewpoint of Quality Control*, which was edited by Deming (Shewhart, 1939). In Shewhart's lectures at the Department of Agriculture that provided the basis for this book, he had proposed new rules for presentation of data and also espoused his Cycle for Scientific Inquiry, which has become known as the Shewhart Cycle (see Figure 2) (Shewhart, 1939, pp. 45, 149).

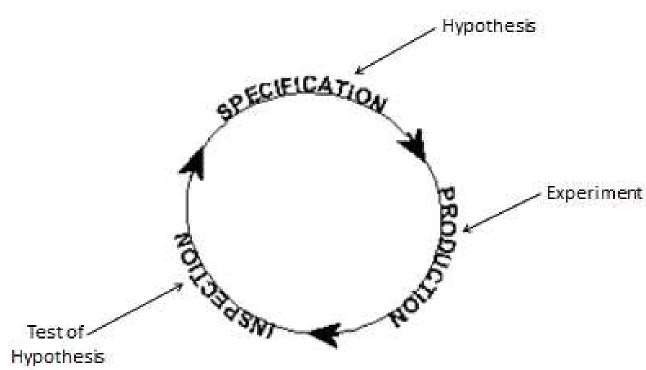

FIGURE 2: Shewhart Cycle Approach to Scientific Quality Management

In the introduction to those lectures, Shewhart described the renaissance in modern quality thinking that had begun in the 1870s and had occurred in parallel with advances in the state of the industrial revolution. He focused on development of a state of statistical control which must be evaluated considering three aspects: first, as a characterization of the state of control of a manufacturing process; second, from the perspective of the operation which is placed into control; and third, as a judgment that is made about potential future process performance based on observations of past performance and specific knowledge about how the process operates (Shewhart, 1939, pp. 1-7). “This [approach] is necessary if we are to see how the attainment of the economic control of the quality of a manufactured product involves the coordination of effort in the three steps: specification, production, and inspection (emphasized in original text by Shewhart)” (Shewhart, 1939, p. 8). Shewhart displayed these steps to describe the way science influences the commercial process in the Shewhart Cycle.

Shewhart used an analogy to compare this business development cycle to the process of scientific investigation based on formulating and testing research hypotheses which he claimed would “give valid predictions” (Shewhart, 1939, p. 42) only when the process operated in “a state of statistical control” (Shewhart, 1939, pp. 43-45). The state of statistical control can be judged using a control chart because it will reflect the absence of special cause variation and the presence of stability in process outcomes. Achieving this state of control represents the highest good or level of excellence that can be achieved in a pragmatic world, where under the existing conditions operational knowledge approaches the level of scientific laws. Thus, the three steps that Shewhart (1939) identified (e.g., specification, production, and inspection) are analogous to what he defined as the three steps of scientific inquiry: hypothesis, experimentation, and analysis (p. 149).

What now is called the Shewhart Cycle represents this sequence of three operations in an evolutionary process of scientific inquiry combined with production (experiment) and inspection (test of hypothesis) that “constitute a dynamic scientific process for acquiring knowledge” and which are applied in a “spiral gradually approaching a circular path which would represent the idealized case where no evidence is found in Step 3 (inspection) to indicate a need for changing the specification (or scientific hypothesis) no matter how many times we repeat the three steps." Furthermore, Shewhart provided a precondition before a system could enter into a state of control: "…for the meaning to be operationally definite, not only certain criteria of control, but also the operation of selecting the objects whose qualities are to be tested, must be specified." The initial step of specification also has an operational precondition: "…the intent of any such specification implies a certain degree of assurance that the quality of the product will be found to satisfy this criterion (sic), particularly when not every piece of the product can be tested," which requires that "the design specification must be supplemented in Step 3 by inspection practices providing adequate data and satisfactory control for each type of product." Also, "…to attain economic control and maximum quality assurance, statistical theory, and techniques must enter every one of the three steps in the control of quality. This potential state of economic control can be approached only as a statistical limit after the assignable causes of variability have been detected and removed. Control of this kind cannot be reached in a day. It cannot be reached in the production of a product in which only a few pieces are manufactured. It can, however, be approached scientifically in continuing mass production" (Shewhart, 1939, pp. 45-46).

Deming also considered Shewhart's four rules for presentation of data to be exceptionally important as a foundation. When paraphrasing Lewis, (1929) Shewhart (1939) stated, "…we cannot have facts without some theory" (p. 88). Deming's foreword to Shewhart's book commented about Shewhart's theory of control, "…any conclusion or statement, if it is to have use for science or industry, must add to the degree of belief for rational prediction" (Shewhart, 1939, p. i).

It is helpful to identify the rules for presentation of data which Shewhart (1939) stated, as described below:

> Rule 1: Original data should be presented in a way that will preserve the evidence in the original data for all the predictions assumed to be useful (p. 88).
>
> Rule 2: Any summary of a distribution of numbers in terms of symmetric functions should not give an objective degree of belief in any one of the inferences or predictions to be made therefrom that would cause human action significantly different from what this action would be if the original distribution had been taken as a basis for evidence (Shewhart, 1939, p. 92).

Again, referring to Lewis, Shewhart (1939) commented, "…closer examination reveals, however, that every meaningful interpretation involves prediction" (p. 92). Scientific knowledge is necessarily a posteriori, that is, based on experience; however, experience can be biased by perception. Therefore, it is important to prescribe proper meaning to the situation. Figure 3 presents the way that Shewhart proposed to integrate the historical interpretation of data through investigation by applying the theory of control to achieve predictable future states.

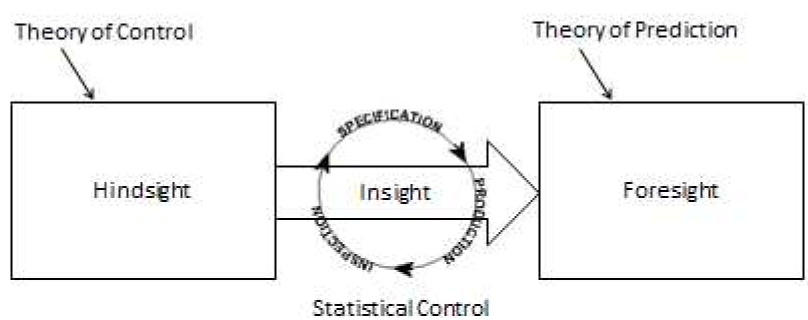

FIGURE 3: Integration of the Theory of Control With the Theory of Prediction

Another area of contribution to Shewhart's 1939 book was the emphasis that he placed on epistemology and meaning of words or semiotics. In addition to considering the philosophical ideas proposed by Lewis (1929), Shewhart also discussed the linguistic concepts of Stuart Chase

(1938), who lived from 1888 to 1985, which was aligned with the method of Alfred Korzybski (1937), who lived from 1879 to 1950. Both of them relied on earlier concepts that had been introduced by Charles K. Ogden, (1889-1957) and Ivor A. Richards (1893-1979) (Ogden & Richards, 1923). Their approach to meaning caused Shewhart to develop a criterion for meaning in association with his theory of prediction, referring to the difference between an observed object and communication about that object in terms of data collection and assignment of meaning to that data to determine what action should be taken.

Shewhart (1939) emphasized "semiotic meaning" (a study of communicative behavior using signs and symbols) and proclaimed "scientific predictions must have definite meanings" (p. 94). He used a pragmatic principle of scientific verification popularized by logical positivists to form a "criterion of meaning" whereby the results of measurement are presented as "meaningful predictions" (Shewhart, 1939, p. 94).

> Criterion of Meaning: Every sentence in order to have definite scientific meaning must be practically or at least theoretically verifiable as either true or false upon the basis of experimental measurements either practically or theoretically obtainable by carrying out a definite and previously specified operation in the future. The meaning of such a sentence is the method of its verification (Shewhart, 1939, p. 94).

Deming later summarized the Shewhart Cycle and its application for prediction in a sentence which inspired the model depicted in Figure 3. "Hindsight supplements foresight: a view backward often adds materially to a view forward" (Shewhart, 1939, p. 149). This sentence identifies the transformation from hindsight to foresight as the period where insight is generated by a process of analytical inquiry and decision making that occurs within what will be called the Bayesian moment, where change projects that will transform the organization so that it can meet predicted future performance requirements are defined. The Bayesian moment (see Figure 1) models a transformative action that should be based on probability; it identifies the outcome of a strategy-formulation process of the executive function, which is the focus of this dissertation. The transformation associated with the Bayesian moment represents a decision that is determined based on consideration of the prior distribution of knowledge as established by hindsight or reflection of past facts. These factors then were described by a probabilistic statement about the likelihood of a future state or a posteriori outcome, which is predictable as a conditional probability to describe foresight.

When writing the Epilogue to Shewhart's second book, Deming referred to Shewhart's specification of a sequence of operations that described a process for developing statistical control as the basis for the subsequent step in the continuing thought experiment regarding the subject of scientific inquiry for the purpose of control (emphasis has been added in the text below).

> 1. Specify in a general way how an observed sequence of n data (sampled data) is to be examined for clues as to the existence of assignable causes of variability.
>
> 2. Specify how the original data are to be taken and how they are to be broken up into subsamples upon the *basis of human judgments* about whether the conditions under which the data were taken were essentially the same or not.
>
> 3. Specify the criterion of control that is to be used, indicating what statistics are to be computed for each subsample and how these are to be used in computing action or control limits for each statistic for which the control criterion is to be constructed.
>
> 4. Specify the action that is to be taken when an observed statistic falls outside its control limits.
>
> 5. Specify the *quantity of data* that must be available and found to satisfy the criterion of

> control before the engineer is to act as though he had attained a state of statistical control (Shewhart, 1939, p. 25).

This quotation from Deming that appeared in Shewhart's (1939) book highlights the idea that human judgment and its psychological implications are significant in the process of structuring statistically based inquiries and the decision-making process. It is also important to note that Deming ends his Epilogue by emphasizing the role of process data sampling and the quantity of data required because this was the focus of the book on sampling theory.

Deming built on the topic of sampling theory in his next installment of the continuing thought experiment with Shewhart. The importance of evidence was stressed by Shewhart as he described the interrelationships that exist naturally between evidence, degree of belief, and the prediction based on the evidence. Shewhart expressed this relationship in a simple drawing (see Figure 4) (Shewhart, 1939, p. 86).

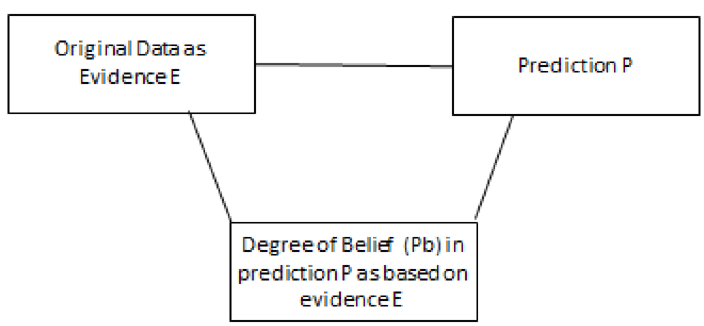

FIGURE 4: Importance of Evidence on Strengthening Degree of Belief

2.4.6 Purposeful Data Collection

In his book, *Some Theory of Sampling*, Deming (1950) emphasized that data-collection system design must be purposeful, when he observed that a "deplorable" type of error in data collection occurs when a researcher designs "a beautiful plan that elicits irrelevant information or sets up protection where none is needed. The first step is therefore to find out what the problem is: what is wanted?" (p. 3). He continued saying, "The requirement of a plain statement of what is wanted is perhaps one of the greatest contributions of modern theoretical statistics" (Deming, 1950, p. 3). Defining a purposeful thought experiment is a prelude to the collection of data samples.

Deming also expounded upon Shewhart's emphasis on sampling as a means to discover distinctions between rational sub-groups in data which led to Deming identifying methods for multi-stage sampling, stratified sampling, and ratio estimates between sampling units. These methods added to the work of Bell Laboratory researchers Harold F. Dodge, who lived from 1893 to 1976, and Harry G. Romig, who lived from 1900 to 1985, regarding acceptance sampling (Dodge & Romig, 1960). Deming's expansion of the theory of sampling and discussion of the impact of differing data types on the process of statistical inquiry distinguished between enumerative and analytic studies of data.

> The distinction between enumerative and analytic studies is extremely important in the design and analysis of either complete counts or samples. In both types of study the ultimate aim is to provide a rational basis for action. A problem exists, and something is to be done about it. In the enumerative problem something is to be done to some portion of the [population] regardless of the reasons why that proportion is so large or so small. In the analytic problem, on the other hand, something is to be done to regulate and predict the results of the cause system that has produced the universe in the past and will continue to produce it in the future (Deming, 1950, p. 247).

Thus, Deming helped to solidify the five-step process which he had identified in the closing comments to Shewhart's second book (Shewhart, 1939) while also addressing the issue of how sampling theory should be considered in the pursuit of statistical control by prediction. He focused on what would be the next step in this developing dialog–more thoroughly distinguishing between analytic and enumerative data analytics.

2.4.7 Deming's Dialogs With Shewhart Discontinued

Throughout this thought experiment with Shewhart, Deming had been the instigator of the dialog and was also responsible for exposing their ideas to the public by editing and publishing the second book that collected and organized Shewhart's papers. However, from 1939 to 1950, Deming was intellectually distracted by his involvement in the war effort and post-war modernization of Japan. Subsequently, between 1950 and 1986, he also was consumed by his consulting work and the popularity that he gained through his work in Japan. In 1967 Shewhart passed away and thus any dialog that Deming had wished to continue on this subject ended. Deming took three additional steps toward advancing his ideas in the coming years.

2.4.8 Statistical Analysis as the Basis for Action

Deming's 1975 article, "Probability as a Basis for Action" (Deming, 1975), advances the experimental dialog concentrating on the point, "the basic supposition here is that any statistical investigation is carried out for the purpose of action. New knowledge modifies existing knowledge" (Deming, 1975, p. 146). Deming emphasized that meaning in measurement comes through the use of a statistically oriented operational definition of the variables that are measured. For this purpose, the distinction between enumerative and analytical studies was "vital in the design of studies and the interpretation of results" (Deming, 1975, p. 147). The objective of analyzing enumerative data is to determine a count or how many of a particular characteristic are observed in a data sample. This summary data determines the overall distribution of performance for a factor and is helpful in identifying risk; however, it is not useful for determining causal systems in processes. The objective of an analytic study is to determine the causal system in the process that produced the outcome that is being studied in order to improve a future performance.

The type of data collection that creates a SPC chart supports an analytic study. Whereas conducting an enumerative study focuses on the sample that exists, an analytical study focuses on future performance results. Thus, Deming concluded that scientific investigations should follow the analytic study approach to discover causal systems of behavior among quality characteristics so that economical outcomes could be generated.

2.4.9 Deming's Final Observations

During the time that Deming was engaged as a statistical consultant between 1950 and 1990, he focused on his practice and reporting conclusions that he drew from his relationships with managers that were his clients. His observations from this period appeared in his book, *Out of the Crisis* (Deming, 1986); however, that book contributed several major ideas which later became the elements of the system of profound knowledge. These linked with Deming's past dialogs with Shewhart on three key points: first, their discussion about measurement and variation and the role of leadership and decision making; second, making further distinctions between assignable and unassignable variation; and third, refining the Shewhart Cycle into what now is called the "Deming Wheel" for management of design and production.

With respect to the first of these points, Deming (1975) identified the challenges that variation produces for leaders, commenting, "The central problem in management and in leadership… is failure to understand the information in variation… The type of action required to reduce special causes of variation is totally different from the action required to reduce variation and faults from the system itself" (p. 309). Such leaders would have a very different understanding of statistical applications. In particular, they would "understand the meaning of the capability of a process and of a system of measurement..." and "…why costs decrease as quality improves. It is essential, however, in industry and in science to understand the distinction between a stable system and an unstable system, and how to plot points and conclude by rational methods whether they indicate a stable system" (Deming, 1975, pp. 309-310). Deming believed that leaders need to understand variation, and he emphasized that "improvement of the system, downstream [toward markets] or upstream [toward suppliers] is the responsibility of management to perceive and to act upon" (Deming, 1975, p. 371). "Good leadership requires investigation into possible causes" (Deming, 1975, p. 115). To do this type of an investigation requires "understanding of variation, special causes, and common causes, and the necessity to reduce constantly the variation from common causes, is vital" (Deming, 1975, p. 136). In fact, "leadership takes a major step forward when they [just] stop asking for explanations of random variation" (Deming, 1975, p. 136). This means that business leaders should be able to truly discern between what Deming calls common cause variation and special cause variation.

Regarding the second point, Deming separated variation into two categories, as Shewhart had done, but he labeled them differently: special cause variation (this is what Shewhart originally called assignable variation) and common cause variation (which Shewhart originally called unassignable variation). Deming introduced these terms to distinguish between the sources of variation–those that could be identified in routine work processes and therefore assigned a responsible party for addressing corrective action and those where the causal system of variation could not be identified and therefore not assigned to a particular manager for improvement. The sources of variation where the cause cannot be identified are the common causes of variation which are designed inherently into the system. Therefore, improvement of this type of variation must be systemic and directed through projects that are initiated by the organization's management so that an extensive transform of the way of working will occur (Deming, 1975, pp. 309-370). Leadership must focus on improvement and transformation. "The aim of leadership should be to improve the performance of man and machine, to improve quality [of the output or deliverable], to increase output, and simultaneously to bring pride of workmanship to the people" (Deming, 1975, p. 248).

The third point involved the work of leaders, which Deming indicated requires informed oversight of the entire system that exists in the organization. The profound knowledge required to transform an organization is derived from the systematic, continual study of its end-to-end processes with the key objective of finding opportunities for improvement. According to Deming, this pursuit was going to be a new job for management. The process for driving this transformation is associated with Deming's modification of the Shewhart Cycle, so that it would be understood more comprehensively (see Figure 5) (Deming, 1986, p. 88).

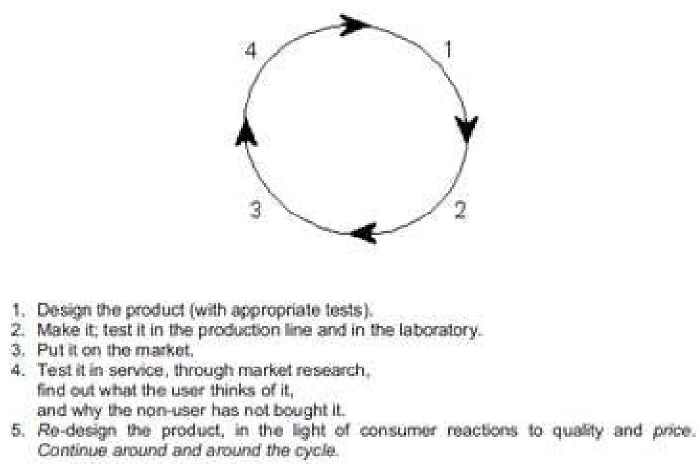

FIGURE 5: Deming Wheel as an Augmentation to the Shewhart Cycle

Deming's (1944) book, *The New Economics*, should be considered as reflecting the final conversation in the dialogue between Deming and Shewhart. In this book, Deming broadened his commentary to distinguish between the roles of workers and managers in the process of organizational change. Deming also offered another perspective on the Shewhart Cycle, which was a modification of his prior model (see Figure 5) that the Japanese had structured into what they called the PDCA Control Cycle. Deming's version of that model was intended to emphasize that this learning cycle is part of the job of a transformational leader. Deming presented his modification in a chapter of *The New Economics* that addressed managing people and followed his commentary on leadership. The Deming Wheel (see Figure 6) represents a "flow diagram for learning and for improvement of a product or of a process" (Deming, 1994, pp. 131-132). In this dissertation, this PDSA version will be referred to as the Deming Wheel to differentiate it from the Shewhart Cycle and the Japanese PDCA Control Cycle.

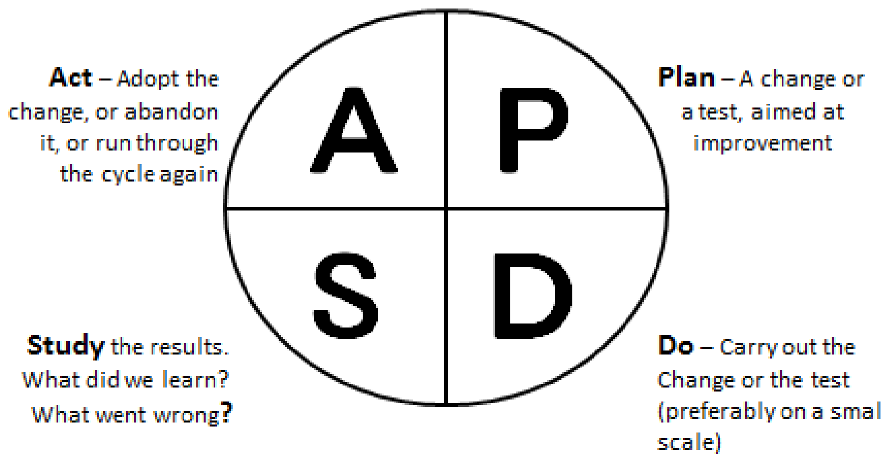

FIGURE 6: The Deming Wheel—Based on the Shewhart Model for Learning and Improvement

There is a meaningful distinction between the models offered by Deming and the Japanese PDCA Control Cycle. Shigeru Mizuno (1910-1989) was the Chairman of the Union of Japanese Scientists and Engineers Quality Control Research Committee, which had been established in 1948 to study quality methods for adaptation in Japan. This group served as the primary developer of the Japanese PDCA Control Cycle. In his own book on this topic, Mizuno revised the Deming Wheel as it had been presented by Deming in his early 1950s lectures. The Japanese PDCA Control Cycle initially had been applied to the control of improvement (Mizuno, 1988, pp. i-v, 9-13). Mizuno described quality control in pragmatic human terms as "the art of doing the obvious and doing it right" (Mizuno, 1988, pp. i-v, 9-13). The Japanese PDCA Control Cycle is illustrated in Figure 7, and this mental model was adopted universally by the Japanese quality movement as a standard for its approach to continual improvement of work.

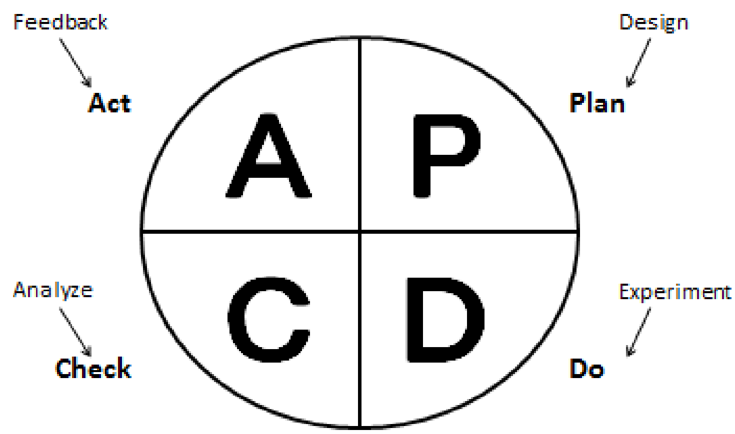

FIGURE 7: Japanese Continual Improvement Model for TQM

Deming (1990) considered the Japanese PDCA Control Cycle as being corrupted by Taylor's concept of attaining quality through inspection. He replaced the term "check" in the cycle with the term "study" to indicate that this cycle represented a learning process. However, the Japanese never incorporated Deming's revision and consistently have retained their PDCA Control Cycle.

The term "study" has some unintended implications, as reflected by synonyms such as "look," "observe," "reflect," "think," "formulate," "structure," "evaluate," "summarize," and "recommend." It misses some of the critical meanings associated with the term, "check" that are considered to be important in Japanese management. The word "check" is associated with the synonyms "look," "observe," "compare to standard," "reflect on differences," "evaluate new ideas," "integrate," and "recommend." The Japanese believe that comparing quality performance to standard performance requirements is essential. Therefore, the Japanese do not view the word "study" as being an appropriate substitute for the word "check." The meanings associated with the Japanese PDCA Control Cycle support the model's use for monitoring and improving standard work which is to be performed in the daily management system of a Japanese enterprise. By changing this term to study, Deming actually implied a more relativistic meaning–a more subjective outcome that might be possible if there is no standard of comparison for the level of quality or attainment of excellence.

What is obvious to one person may not be obvious to another, and what is correct to one person may not be correct for another. How can the subjective nature of such judgments be made more objective? This is why profound knowledge is necessary in the Bayesian moment and why a comparison against a standard is necessary to make recommendations for future change because the magnitude of the gap between actual and standard performance provides an effective means for judging the urgency of making changes.

2.5 Interpreting the System of Profound Knowledge

Thus, the context for Deming's introduction of a system of profound knowledge has been set by tracing the evolution of the Shewhart-Deming dialog. In conducting this inquiry into the linkage between Shewhart and Deming, it has become clear that Deming probably was struggling with the challenge of how to conduct the research that had been recommended by Shewhart (1931) in Appendix 3 of his book (see Table 1) (pp. 473-491). It appears that Deming considered this subject important enough to consume his attention during his final years, when he was not in good health. His book, *The New Economics* (Deming, 1994), presents a system of profound knowledge as a means for the transformation of organizations toward a more comprehensive quality approach. Although Deming passed away in 1993, he left notes to improve his manuscript, and these were incorporated by his daughter, Diana Deming Cahill, in a posthumously released second edition of the book (Deming, 1994). Unfortunately, Deming apparently never conducted the systematic academic research into the history of the four categories that would have supported the content of his proposed system nor did he ever directly refer to the associated portion of Shewhart's work. In *The New Economics*, Deming only referred to contributions from individuals who had influenced his understanding of this problem and coincidentally were mostly his friends or students or whose work he had studied over the course of his consulting career (Ackoff & Emery, 1972; Churchman, 1968; Churchman, Ackoff, & Arnoff, 1957; Johnson, 1992; Lewis, 1929). Thus, Deming's theory of a system of profound knowledge should not be considered academically rigorous in its pursuit of Shewhart's proposed research plan. Despite this constraint, much can be learned from the hints that Deming recorded in his book.

Several researchers have attempted to decrypt the enigma that was embedded in Deming's description of his system of profound knowledge (Canard, 2011; Cole, 1987; Cunningham, 1994; Deming & Arnoff, 1957; Leonard, 2012; Mauléon & Bergman, 2009; Strickland, 1995; Towns, 1997; Wilcox, 2003); however, most mistakenly related it back to Deming's 14 points that he had introduced in his lectures and documented in his book *Out of the Crisis* (Deming, 1986). As previously described, however, Deming stated that this system provided the context for his 14 management points and not the other way around (Deming, 1994, p. 93). So the 14 points should be interpreted in light of their application to Deming's system of profound knowledge.

So, how did Deming provide the context for his system? He introduced the concept of profound knowledge and described the system's elements in the early chapters of his book (Demining, 1994). He began his inquiry by asking the performance-related question, "How are we doing?," and then he followed up with another question, "By what method can new leaders bring improvement?" (Deming, 1994, p. 1). Deming emphasized that "the system of profound knowledge comprises an outside view essential to the management of a system" (Deming, 1994, p. xi). He focuses on the responsibility of management and notes that "…quality is determined by top management. It cannot be delegated–an essential ingredient that I call profound knowledge is missing" (Deming, 1994, p. 17). Deming was always adamant that quality requires executive leadership. "The president's supposition that he can resign from his obligation to lead improvement of quality is a glaring fallacy" (Deming, 1986, p. 127). Deming's statement clearly identifies the role of executives as critical in organizational improvement.

Deming (1986) wrote, "The central problem in management, leadership, and production is failure to understand the nature and interpretation of variation" (p. 465). According to Deming (1994), to achieve reliable quality, "…the prevailing style of management must undergo transformation," and "it is management's responsibility to look ahead, predict… management's foresight" (p. 38). This is because a system "…cannot understand itself. The transformation requires a view from outside" (Deming, 1994, p. 92). This outside, objective view is provided by what Deming (1994) calls a "…system of profound knowledge. It provides a map of theory in which to understand the organizations in which we work" (p. 92). Deming (1994) believed that "the first step is transformation of the individual [e.g., the executive decision maker who is to provide the leadership that creates the transformation]. The transformation is discontinuous. It comes from understanding the system of profound knowledge. The individual, transformed, will perceive new meaning to his life, events, to numbers, and to interactions between people" (p. 92). Finally, he stated, "…the layout of profound knowledge appears here in four parts, all related to each other: appreciation for a system, knowledge about variation, theory of knowledge, (and) psychology" (Deming, 1994, p. 93). The structure that he described in this book makes clear that the leadership of organizations is most pertinent for the proselytization of his system of profound knowledge. The chapters following his definition of this system discuss the subjects of leadership and managing people.

One of the oversights in Deming's (1986) book, *The New Economics* was his failure to define the term, "profound knowledge" operationally. Deming uses this term to establish a requirement for statistical knowledge that needs to be gained in order to characterize process performance through the application of data analysis using Shewhart's theory of control and the statistical methods that he helped to develop. Their relationship and history was described by Deming in Chapter 8 of *The New Economics*. Thus, profound knowledge supports EDM; however, it is also applicable at the working level of organizations, where the content of profound knowledge can be discovered. Obtaining profound knowledge increases the confidence of decision makers and thereby contributes to making a difference in decision outcomes by achieving higher probability of success in achieving an organization's purpose (Deming, 1994, pp. 92-115).

The extent of applicability of Deming's system of profound knowledge may be extrapolated from the context which he established for its application; this includes the full range of topics required for cross-functional management of organizations. In both of his books, *Out of the Crisis* (Deming, 1986) and *The New Economics* (Deming, 1994), he used the same illustration to demonstrate the wide applicability of his thinking across the entire end-to-end operational chain of business activity within organizations from the supplier to distribution to the user or final customer as illustrated in Figure 8 (Deming, 1956, pp. 3, 58).

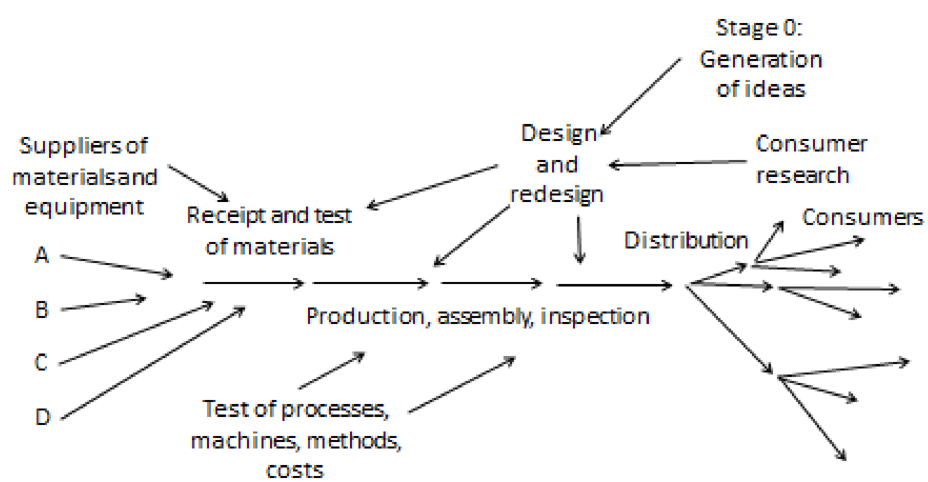

FIGURE 8: Production Viewed as a System of Operational Activities

It is clear that Deming used his concept of profound knowledge within the context of the Shewhart Cycle and the levels of maturity contained in the theory of control which were presented by Shewhart (Deming, 1994, pp. 131-134). He presented the four elements comprising his system of profound knowledge as an integrated set that "…cannot be separated. They interact with each other. Thus, knowledge of psychology is incomplete without knowledge of variation" (Deming, 1994, p. 93). Deming focused application of this system on the "leader of transformation and the managers involved," who "need to learn the psychology of individuals, the psychology of a group, the psychology of society, and the psychology of change" (Deming, 1994, p. 95). This is the only way to build effective cooperation across all human elements involved in the processes and functions required to make the system work efficiently and serve its customers. Deming identified the elements of productive operations as a sequence of activities in which the act of design provides a feedback loop for alignment of the deliverable based on consumer research. This model was presented in numerous lectures as his way of describing the integrated set of tasks that are required to deliver quality outcomes to the consumer through combined design and productive processes (Figure 8). It may be concluded that profound knowledge provides the deep understanding of how Deming's system operates over time.

Deming presents his system of profound knowledge as a dogmatic definition of how things are, but this does not pass the test of a true scientific theory. Scientific theory is demonstrated to be valid by the negation of its logical alternative commented Karl Popper (1963) (1902-1994).

> Science must begin with myths, and with the criticism of myths; neither with the collection of observations, nor with the invention of experiments, but with the critical discussion of myths, and of magical techniques and practices. The scientific tradition is distinguished from the pre-scientific tradition in having two layers. Like the latter, it passes on its theories; but it also passes on a critical attitude toward them. The theories are passed on, not as dogmas but rather with the challenge to discuss them and improve upon them (pp. 66-67).

In the case of Deming's system of profound knowledge, however, he asserted the presence of profound knowledge and described it anecdotally. He did not define what he meant by it—other than identifying the four categories to describe it. Additionally, he did not identify the nature of its origins or specify the myths that formed its development. Deming also did not define any logical alternative hypotheses to his concept of profound knowledge. In fact, he never formally stated a hypothesis and, therefore, it is not possible to state a succinct, reasonable argument against it or endorse it. Deming's approach is contrary to the standard approach for developing scientific knowledge, which begins with a hypothetical condition to be evaluated.

How should Deming's system of profound knowledge be summarized for easy assimilation? The system must be considered in the context for which it is offered--the ability to provide the executive function with profound knowledge necessary to transform organizations into more capable ones that are able to meet future predicted performance needs, which Deming also defined loosely. Based on this relatively sparse definition, a summary of the salient features of Deming's system is presented below in Table 2:

Subject	System of Profound Knowledge
Responsible	Leadership
Motivation	Organizational Transformation
Operational Definition	None
Logical Alternative	None
Criteria for Negation	None
Component Elements	Appreciation of a System
	Knowledge of Variation
	Theory of Knowledge
	Psychology

Execution Model	PDSA Model for Learning and Improvement

TABLE 2: Summary of the System of Profound Knowledge Developed by Deming

Managing successful breakthrough types of change requires a lot more attention to detail and emphasis than does managing routine process change because organizational change is a form of social transformation in which the entire culture must shift to accommodate innovation. Therefore, executives in charge of the organization must lead such transformation. However, Deming did not specify exactly what should be done nor did he offer explicit advice as to how this change should be accomplished. Instead, he offered anecdotal examples, rather than creating operational definitions of the four key components comprising his theory. However, it is possible to summarize the meaning that has been evoked by his descriptions of these four components as described in the following sections:

2.5.1 Appreciation of the System

This element considers thoughtful reflection and insightful characterization of the content and dynamics of the system that is the target for focused change management projects. This includes the system's tangible and intangible components as well as the historical perspective and projection of future capabilities. Understanding both the capabilities and vulnerabilities of the system is required. Deming's ideas on this subject were most strongly influenced by his friendship and association with Russell L. Ackoff (1972), who lived from 1919 to 2009, and who participated in a video series dialog with Deming about the idea of systems thinking. However, Deming ignored others who contributed to this field during his lifetime--especially the work of defining general systems theory by Ludwig von Bertalanffy (1969), who lived from 1901 to 1973, systems dynamics by Jay W. Forrester (1961), who lived from 1918 to 2016, and related research in the field of computer-systems applications which grew out of the theory of cybernetics by

Norbert Wiener (1961), who lived from 1894 to 1964. In fact, although Deming had cited their early writings on operations research, he provided no direct evidence that he had studied any of the major books of C. West Churchman (1968), who lived from 1913 to 2004, or Ackoff (1972), which actually are more germane to the topic of systems than their early book (Churchman, Ackoff and Arnoff, 1957).

2.5.2 Variation

Understanding of the impact of variation in process inputs for the system and development of profound knowledge about the consequences of that variation over time for both the drivers of special causes as well as those for the common causes is the basis for this element in the system of profound knowledge. This knowledge must be able to identify the factors associated with variation in process performance outputs. This profound knowledge permits management to make strategic decisions about what projects should be initiated to gain control over the system and stabilize its outcomes so that predicable forecasts of its future performance are within the bounds of acceptably manageable risk. This material draws directly from the many years of thinking experiments that were conducted with Shewhart.

2.5.3 Theory of Knowledge

The theory of knowledge, the third element of the system of profound knowledge, encompasses the philosophical study called epistemology. Understanding the theory involved in gaining knowledge of process performance, including the people involved and their decisions, is essential to conducting the successful analysis of the data from observations of system performance. Deming paraphrased Clarence I. Lewis, saying, "…the theory of knowledge helps us to understand that management in any form is prediction" (Deming, 1996, p. 101) and that "…knowledge is built on theory" (Deming, 1996, p. 102). Why is theory of knowledge so important? That theory requires an understanding that a statement about reality intended to convey knowledge must “predict future outcomes, with risk of being wrong, and… it fits without failure observations of the past” (Deming, 1996, p. 102). So, theory is important for interpreting facts to gain the ability to make sound predictions. Given this assertion; however, Deming created his views based just on Lewis, who was one of the least influential contributors in development of the philosophy of pragmatism as applied to epistemology, and even then he only emphasized ideas from one of Lewis’ books, *Mind and the World Order* (Lewis, 1929). In discussing epistemology, Deming did not consider the more extensive, earlier contributions of Peirce (1877) or the more consequential contributions of Dewey—most particularly his book on inquiry, *Knowing and the Known* (Dewey, 1910; Dewey, 1929; Dewey & Bentley, 1949).

2.5.4 Psychology

The final element of the system of profound knowledge was psychology, described as insight into how to create intrinsic motivation of employees in order to gain their collaboration and participation in change initiatives that transform an organization. However, Deming focused mostly on the idea of incentives and employee appraisal in his discussion. He described the need for “joy in work” which was derived from “joy in learning,” and he was adamant about how employee appraisal destroyed employee motivation (Deming, 1994, pp. 60, 107-115, 145). He did not address the learning that came from a long series of contributions which created insights into the human side of work based on the research of Mary Parker Follett (1942) who lived from 1868 to 1933, Lillian M. Gilbreth (1914) who lived from 1878 to 1972, Chester I. Barnard (1938), Herbert A. Simon (1945), and many other psychologists whose contributions came after the 1950s. In fact, Deming cited no research for the ideas he expounded in describing this element of his system.

Deming did recognize that the system of profound knowledge had limits beyond which any hope for improvement is merely wishful thinking. Figure 9 (Deming, 1986, p. 323) illustrates how

Deming perceived the inherent limitations associated with continual improvement of results for a causal system. Such a system requires development of profound knowledge to provide an innovative project that can push performance beyond the inherent limit of the system (Deming, 1986, pp. 321-324).

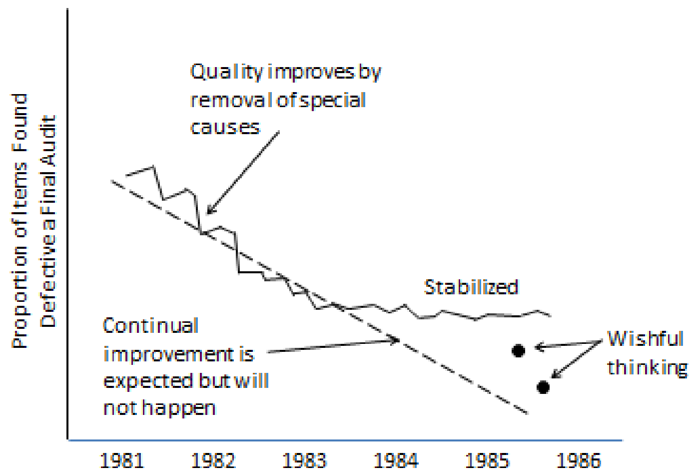

FIGURE 9: Limitations of Causal System Improvement

Deming cautioned managers to “beware of common sense” (Deming, 1994, p. 38) and avoid thinking that creates a wish or “hope for instant pudding” (Deming 1986, p. 126), an instantaneous solution that anticipates resolution of complex problems without doing the requisite smart work needed to conduct an investigation to discover profound knowledge. What does an inquiry into profound knowledge actually look like?

Putting these four elements of the system together into a single sentence will help to make sense out of them. to gain profound knowledge, one needs to observe the system, measure its variation in order to discover the hidden knowledge in the causal systems based on a theory of knowledge that helps to interpret and predict outcomes in conjunction with psychological interpretation associated with the engagement of people in the process, which results in motivation that stimulates the people’s desire to work. This summary statement allows observation of the four elements of the system of profound knowledge, providing an integrated, collaborative, and holistic process as it forms the meta-system for profound knowledge which must itself exist as a system.

Profound knowledge is required for EDM, but it also applies to other levels of every organization. Obtaining this degree of knowledge increases confidence of decision makers and contributes to making a difference in decision outcomes by achieving a higher probability of success (Deming, 1994, pp. 92-115). Deming applies profound knowledge within the context of the Shewhart Cycle and the levels of maturity contained in his theory of control (Deming, 1994, pp. 131-134). However, the preceding discussion also makes it clear that Deming missed many lessons because he did not extend his research beyond the basic content of Shewhart's theory. What else did Deming miss? This inquiry will continue in Chapter IV, where a more detailed inquiry into the development of related literature will probe into all aspects of profound knowledge. However, at this stage of the inquiry it is important to establish the fundamental framework for the analysis that will be conducted throughout his dissertation--the mental model of the Bayesian moment which was introduced previously.

2.6 Proposal of a Mental Model for Research Investigation

The preceding discussions permit formulation of a more concise statement of the question, "How to improve quality of EDM through application of a more scientific approach that produces profound knowledge?"

This dissertation research addresses this question using a structured inquiry into the evolution of the concepts behind Shewhart's theory of control and its transition into Deming's system of profound knowledge. The inquiry is based on a generic mental model of EDM that creates transformative change through a continual improvement process, known as the Shewhart Cycle. The research seeks to understand what approaches, methods, techniques, and/or means influence the intellectual roots for development of profound knowledge and which of these factors have affected the success of the EDM processes. Can such methods increase an executive's appreciation for and comprehension of profound knowledge and apply it to improve performance of his or her organization? Will these methods enhance an executive's capability to make better? Will superior opportunities for developing foresight that leads to competitive advantage be created though the process of enlightening and informing executives regarding priorities for opportunities to improve?

Shewhart laid the foundation for this mental model for a scientific approach to EDM with the Shewhart Cycle, which evolved into the Deming Wheel and the Japanese PDCA Control Cycle. Shewhart defined control as: "action for the purpose of achieving a desired end" (Shewhart, 1939, p. 8). To achieve the desired performance result for an organization means that it will achieve its vision of a future state, and to accomplish this, the organization must become capable of making an appropriate judgment of the best course of action–a plan to achieve a quality outcome. Thus, the theory of control becomes the basis for prediction. This is another interpretation of the meaning of quality control that had been developed by Shewhart (1939, p. 1).

Shewhart also had indicated that quality possesses both an objective reality as well as a subjective interpretation. The objective nature of quality is independent of the human observer and is therefore both constant and measureable. However, the subjective component of quality depends on the perception of the observer–how he or she thinks, feels and senses quality in relationship to his or her experience with the objective reality (Shewhart, 1931, p. 54). Thus, a more comprehensive application of Shewhart's work requires a broader framework or a generic approach to EDM to achieve insight for driving an organization toward its future success state. Clear communication must be achieved through the use of past information and current experimentation to create insight. Therefore, Shewhart's theory of control and his recommendation to integrate statistical methods into all aspects of management practice must become essential components of the process of any deliberation process that generates an executive decision

> Since knowing is of the nature of a developing process directed toward the attainment of an idealized state where maximum validity of prediction results, perhaps the most important requirement on the presentation of data is that the results of an experiment should be presented in a way to contribute most readily to the development of the knowing process (Shewhart, 1939, p. 105).

From these intellectual seeds, a more comprehensive mental model for conduct of scientific inquiry can be developed and applied for EDM. The proposed mental model identifies an evolved theory of profound knowledge, based on development of those considerations that are required to make a sound judgment by observation of experience and to forecast future behavior as a probability prediction based on those observations, interpretations, and decisions. Deming himself suggested this model in his Epilogue to Shewhart's 1939 book, "Hindsight supplements foresight: a view backward often adds materially to a view forward" (Shewhart, 1939, p. 149). Thus, the resulting mental model contains three components which are connected at the Bayesian moment of decision making, where a transformation to the future state occurs based on an executive choice about the probability pathway that offers the most favorable outcomes, are described below.

2.6.1 Hindsight

This is the realm of history, where the interpretation of past events (a posteriori) is based on the observations, perceptions, and interpretations of individuals, aided by numerical analysis methods, to detect any patterns of behavior that may exist. This model component was what Shewhart focused on to obtain improved knowledge of past events in order to predict what future performance could be reasonably expected. Shewhart's theory of control relates to the hindsight component of the mental model as do application of his method of statistical control charts and his typology for causation of variation.

2.6.2 Insight

This is the realm of psychology, where a decision maker converts historical data and its interpretations into a decision about future direction or plans that ought to be pursued. These interpretations are based on constraints from internal (a priori) conditions that are influenced by the individual decision maker's understanding of the historical context, the context of the event, the culture within which the observations have been generated, within which any conditional decisions will influence or generate consequences, and by the decision maker's personal collection of moral codes. This occurs at the Bayesian moment, the decision point where a choice is made about the desired future state that ought to occur. This is really an ethical or metaphysical decision about what constitutes a preferred future that ought to be pursued by dedicating resources to carry out the executive decision which will shape the direction of some type of organizational transformation. Each decision that an executive makes must be based on a probabilistic assessment of the facts, occurs during the insight process. Deming's system of profound knowledge and Shewhart's Cycle for scientific discovery (and its derivations in the Deming Wheel and the Japanese PDCA Control Cycle) are all related to the processes in the insight component of this mental model.

2.6.3 Foresight

This is the realm of science, where probabilistic projection migrates to become established true belief that is verging on an exact law of science. The purpose of science is to develop validated belief systems about the way the world works in general. Thus, the future only exists as a probabilistic state, and it becomes clearer through subsequent analysis that attempts to invalidate the belief upon which the working hypothesis was based, replacing it with a proposition of higher relevance as the probability more closely approaches undisputable fact. Perhaps this is what Shewhart had considered when he observed that his model was really a "dynamic process" that was more like a "spiral gradually approaching a circular path" as the theory became more profound or evident (e.g., the probability of its truth increased toward the boundary of certainty) (Shewhart, 1939, p. 45). Bayesian decision theory is a key aspect that influences the consideration of decisions in the Bayesian moment, and it deserves a little more explanation at this point. A mental model of the Bayesian moment is presented in Figure 1. The fourth element of Deming's system of profound knowledge combines the three elements of the model into a cohesive structure, representing epistemology or the theory of knowledge.

2.6.4 The Bayesian Moment

Reverend Thomas Bayes (1763), who lived from 1702 to 1761, originated the concept of conditional probability, which has been named in his honor as Bayes Theorem. Bayes Theorem infers a new way of thinking about probability that transitions from the historical consideration of a frequency distribution into a conditional belief or proposition, and it is most frequently described mathematically as the "Probability of A (a future state) given the Probability of B (a prior state)." Bayes paper was published posthumously, and it was only in the latter half of the last century that its application became more prevalent. So, his methodology awaited application for many years (Molina, 1931, pp. 273-283).

The Bayesian moment or point of decision in this mental model of human inquiry signifies a period in time where the scientific method can be applied to observations generated from hindsight illuminated by the system of profound knowledge to produce insight that permits a choice which creates a future state transformation by execution of decisions that generate the expected condition of the foresight. In analytic terms, a Bayesian moment recognizes that this choice represents a conditional probability which is written in symbolic form as $P(A|B)$ or the probability of occurrence of event A given the prior occurrence of event B. Event B is generated by hindsight (a posteriori knowledge), and A is a probabilistic event associated with a future state which is predicted by foresight. The insight component recognizes a decision maker's psychological choosing or judgment mechanism to select an option that has been generated from the hindsight and is executed to create the foresight. It is the generation of an appropriate transfer function that creates the potential for organizational transformation. In the execution of the strategic decision through a change management process, the organization realizes this potential. This model fits the application of customer-experience measurement and provides insights into certain philosophical questions that these circumstances raise (ontological, metaphysical, and epistemological) while requiring psychological understanding of the human being who is conducting the decision-making process. Extrapolations of this model will be explained sequentially as the explanation provided by this research progresses.

During this Bayesian moment the condition of profound knowledge is produced. The way that the term "knowledge" is used in this dissertation drives from the way that economist Frederick A. Hayek (1945), who lived from 1899 to 1992, observed knowledge as dynamic and influenced by the social interactions among individuals and organizations. Although knowledge is built on human relations in social situations, it is also context-specific, and it depends on its integrity and veracity based on its particular location in time and space, which defines its historical boundary. If the context is missing, then the data only can be informational (e.g., an answer to a question), but it does not represent enduring knowledge as it is subject to revision based on understanding of its contextual meaning (Hayek, 1945, pp. 519-530). In an interesting essay on knowledge management, Ichiro Nonaka (2000), born in 1935, described his view that knowledge is created when tacit knowledge is crystallized into explicit knowledge. He held that this transformation occurs in a "shared context in which knowledge is shared, created, and used." Nonaka refers to this circumstance using the Japanese term "BA," which means "place." BA "provides the energy, quality, and place to perform the individual conversions and to move along the knowledge spiral" (Nonaka, Toyama, & Konno, 2000, pp. 5-34). This concept also describes the activity that occurs during the Bayesian moment. However, profound knowledge is more than a transition from tacit to explicit knowledge, and it is more than just answers to questions or information. It represents wisdom as it is predictive of future events or outcomes and involves more than just place or location because it is dynamic in the sense that it changes with respect to time. Wisdom has permanence because it describes behavioral patterns of people, organizations, materials, etc. As knowledge increases in probability and veracity, information transitions to profound knowledge, incrementally increasing to higher levels of predictive capability and becoming more valuable for determining future plans and making decisions.

The EDM process occurs within the Bayesian moment, where a scientific inquiry is conducted to transform historical knowledge of past performance in order to shape strategic decisions. Those decisions identify and initiate change projects and deliver predicted expectations for future performance. The Bayesian moment mental model is significant in transformation of an organization from its historical way of working; it stimulates change that creates a future way of working, and that new approach possesses a high probability of success. Thus, it is very important to understand clearly what happens to gain insight and generate profound knowledge during this Bayesian moment from the perspective of the individual who has the rights to make transformative decisions—the organization's executive function as originally described by Barnard (1938) and Drucker (1954) Gaining increased enlightenment about the operation of the Bayesian moment is a focus of this study.

The fact that Deming was attempting to refine Shewhart's thinking in his final book, *The New Economics*, (Deming, 1994) is evident by the way he transitioned the Shewhart Cycle into the Deming Wheel. Although the Japanese PDCA Control Cycle incorporated this concept, Deming never embraced that model. To complete development of this application of the scientific method for EDM, it is essential to learn how further refinement of Deming's thinking became Japanese TQM (this subject is addressed in Chapter IV).

The context in which Deming presented his ideas regarding profound knowledge is important: He was addressing the executive task of organizational transformation using his proposed framework to improve decision making with respect to special cause variation--the profound knowledge required to change a system based on a statistical understanding of a specific process or work activity. However, he interpreted Shewhart in the context of its potential impact on EDM, which should be based on an understanding of the system components of common cause variation that exist in the design of the system. Also, Deming did not limit his theory or method to manufacturing processes but attempted to generalize them to the decision problems of all executives facing the challenge of transforming their organizations to improved levels of performance. The purpose of executive-led transformation is to remain competitive as the organization is affected by changes in environmental, situational externalities that create the need to review past decisions continually and assure that they remain relevant to salient facts that are exposed as time passes and the future is revealed progressively.

Key questions are "Would the conditional decision for choice of a current strategic direction change as fidelity in knowledge affecting the choice about future actions improves?" and "What justifies this interpretation that essentially broadens Shewhart's thinking process?" The answers are found in Shewhart's recommendations regarding future research which must be coupled with an interpretation of Deming's motivation for his theories related to quality. Although this introductory chapter limits its discussion to questions related to the linkage between Shewhart and Deming, some assumptions were necessary and were identified earlier.

Chapter III of this dissertation presents the research methodology for developing a theory of profound knowledge using the phenomenological research method that is called "grounded theory" and validation of this theory through the use of a survey of both academic and practicing experts in the field of quality.

Chapter IV describes the inquiry into the thinking pathways of the grounded research, considering the nature of the relationship between the three core components of Shewhart's methodology and the elements of the system of profound knowledge proposed by Deming. It also discusses the intellectual pathways that Deming failed to pursue in his rudimentary inquiry into the definition and nature of profound knowledge and the research directions that Deming should have developed to establish a more comprehensive theory of profound knowledge based on academic inquiry.

CHAPTER III

METHODOLOGY: PURSING AN INQUIRY INTO THE NATURE OF PROFOUND KNOWLEDGE

This chapter describes the methodology used in this dissertation for generating a grounded theory of profound knowledge based on Deming's conceptual framework for the system of profound knowledge. It documents the research approach for conducting this inquiry into the nature of profound knowledge to discover the conceptual categories and their properties which more comprehensively define the dimensions of theory that were postulated in the framework presented by Deming. This chapter also describes an approach to validate the emergent theory through a survey of recognized experts with academic and practitioner experience.

3.1 Research in Pursuit of Profound Knowledge

Deming postulated four categories of interest in his system of profound knowledge. In Deming's *The New Economics*, (Deming, 1994) it is clear that he never attempted to conduct an exhaustive or comprehensive examination of this subject. His attempts at defining the four components identified as a system of profound knowledge were both highly subjective and uninformedly superficial. Deming's exposition also lacked contextual academic references; therefore, it is not possible to directly develop a theory based on his unusually structured commentary. In short, it is fair to conclude that Deming failed to pursue an adequate research design in creating his presentation of the system of profound knowledge. The informal approach represented by this framework failed to define this system adequately and what he did state was restricted to declarative statements about the definition, application, and value of the system he espoused. Deming postulated that this construct was an essential component required for transformation of industry. In this respect, Deming actually applied a phenomenological approach to construct his proposed paradigm of profound knowledge without any supporting scientifically based data. However, his concepts were anecdotal, and he made no effort to associate his paradigm into a historical context of the development of mankind's approach or dialog about quality.

Although Deming did provide a categorical decomposition of profound knowledge (appreciation of systems, variation, theory of knowledge, and psychology), his philosophical construct for the model was purely subjective, however, some of that framework can be inferred from his work with Shewhart. Deming failed to establish the objective of the transformation, but he further postulated that the Deming Wheel was the mechanism by which transformation could be obtained as a learning experience without offering any supporting evidence.

Phenomenological research is performed by analyzing the research subjects to understand and interpret their unique experiences. This type of study differs from an epistemological study where the researchers observe the participants directly to make their distinct observations, which consist of measurements and behavioral observations (Creswell, 2013, p. 20). The methods of social research attempt to search for meaning in the essence of experience, where behavior and description formulate an "inseparable relationship" (Creswell, 2013, p. 21).

Should the argument Deming presented be characterized as following a coherent research method? Charitably speaking, Deming conducted a very loosely constructed phenomenological research study, and his essay on profound knowledge was largely a subjective assessment based on anecdotes drawn from personal experience and supplemented by stories repeated from the experience of his ardent supporters. To understand the weaknesses inherent in Deming's proposed mental model, it is necessary to understand how a true phenomenological study is conducted, as well as how its data is drawn to create theory from practice. This will make it clearer that Deming failed to apply the rigorous methodology required for acceptable phenomenological research—particularly in the use of the grounded theory research method.

3.2 Research Questions Pursued in This Dissertation

This dissertation investigates the characteristics of profound knowledge. Therefore, the emphasis shifts in this chapter from the prior chapter's research into the relationship between the ideas of Shewhart and Deming regarding the development of a deeper understanding of the interrelationship between their quality concepts and the historical precedents, antecedents, and parallel intellectual developments that contributed to establishing a basis for the development of a valid theory of profound knowledge. Of course, the system of profound knowledge proposed by Deming will serve as the foundation upon which to build this theory. Using Deming's four-dimensional framework, historical research will be reviewed in the following chapter to determine how to characterize the nature of the conceptual categories that define profound knowledge and to identify the means required to pursue and discover the properties of those conceptual categories. Those findings will be applied to developing the theory of profound knowledge in the Bayesian moment to support EDM for strategy formulation processes. This historically based inquiry will establish a framework of logical categories and their properties which will define the set of four dimensional propositions that will support a grounded theory of profound knowledge.

Two questions define the thinking experiment that is addressed in the following chapter of this dissertation:

3.2.1 First Research Questions

What are the categories that operationally define the knowledge framework that is applied during the Bayesian moment to structure managerial choice? How can that framework's properties and operational principles be derived from postulated thinking pathways that have evolved from concepts that were embodied in the system of profound knowledge?

3.2.2 Second Research Questions

How can the system of profound knowledge proposed by Deming be formulated into a comprehensive theory of profound knowledge? How will this theory influence the organizational transformation requirement proposed by Deming in *The New Economics*?

3.3 Methodological Approach Used in This Inquiry

This dissertation engages philosophical, psychological, and sociological research methods in its investigation of profound knowledge through a grounded research approach that is based on the study of phenomena that have evolved over time and evolved into thinking pathways. The term "phenomenology" was originated by Johann Heinrich Lambert (1764), who lived from 1728 to 1777, a Swiss physicist and mathematician, in his book, *The New Organon,* (Lambert, 1764) in which he studied optics as a means to distinguish between objective and subjective forms of knowledge. Lambert's work subsequently influenced the epistemology of German philosophers Immanuel Kant (1921), who lived from 1724 to 1804, as reflected in his book, *Critique of Pure Reason* (Kant, 1921)*,* and John Stuart Mill (1863), who lived from 1806 to 1873, whose philosophy of utilitarianism and psychological approach to logic were precursors to the pragmatic philosophy of Pierce, who recognized Lambert's work in his 1843 book, *A System of Logic Ratiocinative and Inductive* (Mill, 1843). Mill's (1843) logic applied psychological principles to the development of an empirical construct and was based on the influence of Lambert (1764) and Kant (1921). Philosophical methods derived from phenomenology originated in the work of Georg Wilhelm Fredrich Hegel (1968), who lived from 1770 to 1831. Hegel viewed organizational events as phenomena which are perceived as subjective, conscious experience. In his book, *The Phenomenology of the Spirit* (Hegel, 1968). Hegel (1968) sought to develop theory based on the natural "rambling dialog" of phenomena by studying the developmental pathways by which observations of the phenomenon occurred in the human experience and combining related thoughts, leading to "absolute knowledge" or a "consummation of experience" (p. 684). He compared this to "relative knowledge" in which "a thing has only relative existence" (Hegel, 1968, p. 791). Deming appears to use this concept similarly when he refers to Hegel's "absolute knowledge" in conjunction with his description of profound knowledge.

In his major work, *Social Theory and Social Structure*, (Merton, 1949) sociologist Robert K. Merton (1910-2003) described a system of functional content in social organizations as consisting of three distinct structures: manifest functions, latent functions, and dysfunctions. Merton described manifest functions as being those activities that are intended and recognized; latent functions were defined as those activities that are unintended and unrecognized. Merton also recognized that dysfunctions occur when the unintended consequences of system design lead to its instability or breakdown.

Merton introduced the term "paradigm" to the lexicon of modern thought and defined it as "exemplars of codified basic and often tacit assumptions, problem sets, key concepts, logic of procedure, and selectively accumulated knowledge that guide [theoretical and empirical] inquiry in all scientific fields" (Holton, 2004, p. 148) Thomas S. Kuhn (1922-1996) became renowned for his 1962 book, *The Structure of Scientific Revolution* (Kuhn, 1962)*,* where he described patterns, mental models, and paradigms of scientific inquiry. Over time as researchers become more convinced of the settled nature of their knowledge, then they create mental models which emerge to summarize their collective understanding and direct future inquiries toward new discoveries. The system of profound knowledge is an intermediate model of this type and is being used to direct the current research into the nature of profound knowledge. This research will be based on more extensive inquiry into potential lessons to be learned from history. Kuhn (1962) observed that: “in paradigm choice there is no standard higher than the assent of the relevant community… this issue of paradigm choice can never be unequivocally settled by logic and experiment alone” (p. 93). Thus, validation by an extensive group of leading members of a relevant community is essential to establish acceptability of any theory or propositional logic. Kuhn (1984) subsequently amplifed this thought, as follows:

> Concerned to reconstruct past ideas, historians must approach the generation that held them as the anthropologist approaches an alien culture. They must, that is, be prepared at the start to find that natives speak a different language and map experience into diferent categories from those they themselves bring from home. And they must take as their object the discovery of those categories and the assimilation of the corresponding language (p. 246).

Thus, establishment of broadly accepted theory requires integration of a spectrum of ideas that cross historical contexts and disciplinary languages. The challenge that Kuhn identifies must be expected in research into the variety of thinking pathways that will be encountered in the various disciplines that comprise a stream of thinking that has evolved into what Deming described as profound knowledge. These ideas will be incorporated through the intellectual integration of their related concepts based on bodies of knowledge that were codified using distinctly different motivations and emphasizing concepts from unique perspectives. For this reason, a variety of thinking pathways will be investigated independently to understand their influence on the development of an inclusive theory of profound knowledge.

3.3.1 Drawing Theory From Practice

Donald A. Schön (1983), who lived from 1930 to 1997, developed the concept of reflective practice and contributed, along with his Harvard colleague Chris Argyris, to the theory of organizational learning. In his 1983 book, *The Reflective Practitioner* (Schön, 1983), Schön advocated that a new kind of professional knowledge is needed—one that can cope with the complexities of systems and not merely focus on a narrow viewpoint that is doctrinally correct for a specific professional discipline. He noted that research is "institutionally separated from practice" and that this leads to the perception that "scientific research is the basis for professional practice" (Schön, 1983, pp. 26, 38). However, Schön postulated that there needed to be new epistemology of practice that is based on relevance of information where the "practitioners function as the technical experts" and that this would create a sensitive situation due to the fact that often the academic disciplines have become "selectively inattentive to data that falls outside their (distinct) categories" (Schön, 1983, p. 44). Schön (1983) observed the conundrum of investigation into the applicability of science, saying,

> We tend to see science, after the fact, as a body of established propositions derived from research. When we recognize their limited utility in practice, we experience the dilemma of rigor or relevance. But we may also consider science before the fact as a process in which scientist's grapple with uncertainties and display arts of inquiry akin to the uncertainty and arts of practice (p. 49).

In fact, Schön is repeating the argument that was made originally by William James in his 1896 essay, "The Will to Believe" (James, 1896). The beginning of science is a fuzzy domain in which ideas are not formulated clearly, and theories are derived from belief systems that are in pursuit of confirmatory evidence. Schön contrasts "technical rationality" with "reflection-in-action," where technical rationality represents Kahneman's System 1, logical inquiry of science as in "thinking slow" and reflection-in-action represents Kahneman's System 2 with its "thinking fast" or emotive response (Schön, 1983, p. 164). A reflective approach to learning from practice does not separate the means from the ends, research from practice, or knowing from doing. In reflective learning, a practitioner conducts an inquiry through active learning, where "deciding and problem solving is a part of the larger experiment in problem setting." Schön concludes that, "…it may be possible to bring the managing into dialog with management science" (Schön, 1983, p. 241). This can occur when an objective inquiry is made into the phenomena that evolves into theory. Thus, pursuit of the defining phenomena serves as a foundation for the key tenants of an emergent theory, which is a focused or grounded research investigation. What is the concept of phenomenological research? How does research create the emergence of a grounded theory? How can historical data be used as a basis for such research? The following paragraphs will address these three questions.

3.3.2 Phenomenological Research Methods

To understand that Deming need to apply greater rigor in his phenomenological research, and in particular, in the use of grounded theory as a research method, it is necessary to develop an appreciation for phenomenological research methods, which begins with an examination of the work of a reflective practitioner who seeks to make sense out of an inquiry into the behavior of the pragmatic world. What is phenomenological research? Clark E. Moutakakas (1994), who lived from 1923 to 2012, described the ways that phenomenological research methods evolved from the early influences of René Descartes (1996), who lived from 1596 to 1650. Descartes' (1996) approach to rational thinking where knowledge based on intuitional thinking precedes empirical knowledge which inspired Husserl to search for information on Hegel's concept of absolute knowledge (Moustakas, 1994, p. 25). The contribution of Edmund Husserl (1859-1938) was significant; he sought to "acquire knowledge of science through concentrated studies of experience and the reflective powers of the self" (Moustakas, 1994, p. 26).

Husserl's idea of "phenomenological reduction" is a logical investigation process for "meditative knowing" to discover a "subjective foundation for knowledge," and this pursuit consists of two phases or moments. The first moment denotes a preliminary research premise that Husserl called einklammerung (German) or epoché (Greek), which has been translated into English as "bracketing." The term describes an investigatory abstinence or suspension of judgment that occurs when an investigator sets aside prejudices and preconceptions to pursue investigation into some phenomenon objectively. The second moment is the actual reduction, where investigators conduct an objective inquiry where conceptual cognition can be carried throughout intentional analysis (Husserl, 1970, pp. 168-169). "Epoché means to refrain from judgment, to abstain from or stay away from the everyday, ordinary way of perceiving things… [it] requires a new way of looking at things, a way that requires that we learn *to see* what stands before our eyes, what we can distinguish and describe" (Moustakas, 1994, p. 35). Grounded theory is one strategy for pursuing phenomenological research (Creswell, 2013, p. 17). This methodology will be applied for this research to derive the theory of profound knowledge.

3.3.3 Grounded Theory

One of the methods recommended for conducting this type of study is called the Van Kaam method of analysis of phenomenological data in honor of its developer Adrian Van Kaam (1959), who lived from 1920 to 2007. His work preceded the development of the grounded theory approach and created a mental model within which grounded theory could be developed and practiced. The Van Kaam method may be summarized, as follows (Moustakas, 1994, pp. 120-121):

1. Conduct and record interviews with the participants and prepare transcripts of the interviews for subsequent analysis.

2. List expressions that are relevant to the experience being investigated and prepare a preliminary grouping.

3. Reduce and eliminate expressions identified based upon application of two questions. First, does the recorded expression have a moment that is both logically necessary and

sufficient for understanding it? Second, is it possible to summarize and extract the expression by labeling it clearly (without ambiguity, overlapping, or vagueness)?

4. Cluster the labels into core groupings that represent the themes defining the experience.

5. Identify overarching themes for the complete experiential transcript in order to assure it is representative, explicit, and compatible with the recounted experience.

6. Transform the validated and relevant themes into a descriptive narrative of the full experience for each individual participant, including verbatim examples of precise words used in the interviews.

7. Develop a composite description of the experience as whole.

The approach of Van Kaam categorizes observations that are relevant through a process of clustering the themes from the data into logical groupings in order to define the experience. This set of themes then is used to describe the experience as a whole. Grounded theory helped to make this process more explicit.

Grounded theory developed out of the research of Barney G. Glasser, born in 1930 and Anselm L. Strauss (Glasser & Strauss, 1967), who lived from 1916 to 1996, as a systematic research method for the social sciences. It is used to construct theory through an inductive-reasoning process based on the study of qualitative data, which is much broader than interviews. In fact, Glasser described his source for theory development as “all is data” (Glasser, 1998, p. 8) in many of his writings (Corbin & Strauss, 2007; Glasser & Strauss, 1967; Glasser, 1978; Glasser, 1992). If a researcher can “accept that all is data, from which theory can be generated by constant comparisons, then he will accept that grounded theory is a general method that can be used on all data in whatever combinations” (Glasser, 1998, p. 42). Thus, the use of grounded theory (develops)... an integrated set of conceptual hypotheses... probability statements about the relationships between concepts" (Glasser, 1998, p. 3). However, a researcher using the grounded theory approach "must feel comfortable with [the] uncertainty, ambiguity, and confusion that comes initially and during various stages of grounded theory for brief periods. He must trust that uncertainty, ambiguity, and confusion are a useful path to being open to emergence [of the theory]" (Glasser, 1998, p. 44). The result of this research should be a reduction of the data to a "parsimonious theory with scope" (Glasser, 1998, p. 14) that emerges when categories and properties are developed from the raw data of the experiment through a process of classification, sorting, assigning types, and comparison. Often, in a process of conducting such a study, "categorizations are the end point of grounded theory research" (Glasser, 1998, p. 6). The purpose of the study and its validation is to first develop then "modify the theory to fit, work, and be relevant" to the issue that is under investigation (Glasser, 1998, p. 4). Glasser (1998) defined the four criteria for evaluating a grounded theory that emerges from such a study, as follows:

> 1. Fit is another word for validity. Does the concept adequately express the pattern in the data which it purports to conceptualize? Fit is continually sharpened by constant comparisons.
>
> 2. Workability means do the concepts and the way they are related into hypotheses sufficiently account for how the main concern of participants in a substantive area is continual [*sic*] resolved?
>
> 3. Relevance makes the research important, because it deals with the main concerns of participants involved. To study something that interests no one really or just a few academics or funders is probably to focus on non-relevance or even trivia for the participants. Relevance, like good concepts, evokes constant grab.

4. Modifiability is very significant. The theory is not being verified as in verification studies, and thus (it is) never right or wrong (p. 18).

Therefore theory that is derived from grounded research is never accepted completely because it is, like most scientific theory, based on an emerging probability that is stochastic and changing dynamically as new measurements, observations, and hypotheses emerge over time. However, grounded theory is valuable for developing a theory using an exploratory investigation of the core research question by conceptualizing the latent patterns and structure that emerge when data are combined into developmental streams or thinking pathways. These pathways may be discovered during an inquiry into their historical evolutionary development as they become intellectually mature. The recorded thoughts in historical documents are themselves the data that may be traced to generate theories so that patterns emerge and assemble themselves into the coherent system that was proposed.

The system of profound knowledge that was proposed by Deming is the initial starting point for evaluating what thinking pathways should be explored to determine the historical data that has been embedded in the evolution of documents, primarily books and papers, that describe the changing thoughts that have emerged since its origination. Thus, it is the historical documents generated in these pathways that will be studied in this dissertation in compliance with Glasser's (1998) dictum that "all is data" (p. 8).

What is different about the research approach that will be pursued in this dissertation? This research will apply what is called a grounded theory study, which attempts to advance beyond a phenomenological study by digging deeper into the substance of the inquiry. Bracketing, or the concept from phenomenological research that assures prejudices and biases are eliminated from the search for theory, was incorporated in grounded theory by Glasser (1998, p. 24). This requires a focused experience that presents a framework to "generate or discover a theory [as] a 'unified theoretical explanation' for a [specific] process or an action" (Corbin & Strauss, 2007, p. 107). In this study, the focus area will be explaining the nature and substance of profound knowledge.

The output of a grounded theory typically is presented as a categorization of the distinctive components and their decomposition into idiosyncratic categories that are described as a set of unique properties. In this case, the output of the study will be presented in a tabular format as shown in Figure 10; that table will be presented in Chapter V and will provide categories that are divided into conceptual levels. For this dissertation, they will be divided into two types of knowledge that are postulated as the null hypothesis (profane knowledge) and an alternative hypothesis (profound knowledge). Each category is interpreted for each level according to the set of its unique properties that are used to assign relevant findings.

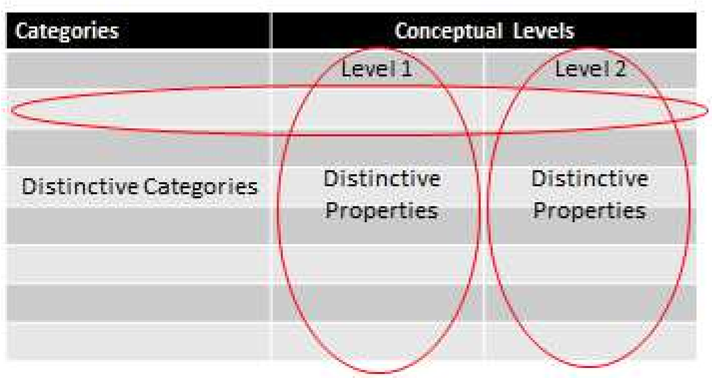

FIGURE 10: Comparative Structure of Grounded Theory Categories and Properties

The data for this grounded-theory inquiry will be historical documents, so the methods of historical research also will be used to develop the architecture for the thinking pathways that will be analyzed.

3.3.4 Historical Research

Historical research can be applied to all fields of study and includes inquiry into the origins, growth, development of theories, personalities involved, and critical events or crises that have occurred. Both quantitative and qualitative observations are included in collections of historical data. Charles H. Busha and Stephen P. Harter (1980) detailed the following six steps for conducting historical research:

1. The recognition of a historical problem or the identification of a need for certain historical knowledge;

2. The gathering of as much relevant information about the problem or topic as possible;

3. If appropriate, the forming of hypothesis that tentatively explains relationships between historical factors;

4. The rigorous collection and organization of evidence, and the verification of the authenticity and veracity of information and its sources;

5. The selection, organization, and analysis of the most pertinent collected evidence, and the drawing of conclusions; and

6. The recording of conclusions in a meaningful narrative. (p. 91)

Several of these steps will be applied in this study. Deming's piecemeal framework of the system of profound knowledge will be used as a tentative set of hypothetical categories. The academic disciplines and managerial functions that have developed since the industrial revolution signaled a need for more structured thinking and development of a body of knowledge related to management. Information will be gathered for each of these pathways in order to evaluate and develop rigorously organized evidence that can be used to identify the most pertinent facts into a meaningful narrative. This approach will allow a conclusive theory to emerge, converging the of categories into a new framework.

Father Gilbert J Garraghan, S. J. (1946), who lived from 1871 to 1942, divided criticism from various sources regarding historical research into six inquiries below that should be considered when assessing the credibility of historical references (p. 168):

1. When was the source, written or unwritten, produced (date)?
2. Where was it produced (localization)?
3. *By whom* was it produced (authorship)?
4. From what pre-existing material was it produced (analysis)?
5. In what original form was it produced (integrity)?
6. What is the evidential value of its contents (credibility)?

The data in this study will be provided by the writings of the thought leaders associated with each of the thinking pathways. The assessment of these writings will seek to determine which ideas contribute to a coherent explanation of the epistemological pursuit of profound knowledge and defining a more comprehensive understanding of the knowledge that is needed to support effective decision making within the Bayesian moment, generating the strategic foresight that is required to formulate choices that will transform an organization and increase its ability to perform successfully in the future.

How can the acceptability of a data source be judged using these criteria to determine the degree of credence necessary for a grounded research study? The data sources should be evaluated based on their perceived relevance by academics and other accepted authorities since the time the document originally was produced. As historian Louis R. Gottschalk (1950), who lived from 1899 to 1975, commented, "…for each particular of a document the process of establishing credibility should be separately undertaken regardless of the general credibility of the author."

How can the veracity of historical data be judged in regard to its use in a grounded research study? Historian C. Behan McCullagh (1984), born on 1948, offers the following advice to researchers, "...if the scope and strength of an explanation are very great, so that it explains a large number and variety of facts, many more than any competing explanation, then it is likely to be true" (p. 26). This pursuit of truth will be analyzed using the framework of historical interpretation, described by Richard E. Neustadt (1919-2003) and Ernest R. May (1928-2009) in their 1986 book, *Thinking in Time* (Neustadt & May, 1986). They combined precedents and analogies to discover historical models that shaped current perspectives. The concept of an analogy is supported by the recurrence of situations and circumstances that occur as repetitive patterns in the conducting of human affairs. To use an historical event as an analogy, it must be extracted from the facts and details which represented its historical reality; this injects a sense of relevance to the category of interest in the research. Neustadt and May obscured the line that separates intellectual or theoretical inquiry from the demands of practical or operational thinking. However, there is a need to distinguish intellectual inquiry from practical thought. In development of a theory, the achievement of incremental performance improvement is typically worth seeking. In fact, all improvement in the way that a theory is developed can be defined that way; the degree of improvement is merely an incremental difference in the magnitude in which improvement occurs. Thus, the incremental advances in human thought that evolve from generation to generation and are observable in influential patterns passed on from one teacher to the next will provide the focus for determining the patterns of thinking and discovering the significant conceptual relationships across the disciplines being investigated.

Because advances in human thought from roughly 1877 to 1993 were linked primarily to disciplinary development, the thinking pathways employed in this study will focus on the evolution of related disciplines that formed the confluent bodies of knowledge that converged into the structural framework proposed in the system of profound knowledge. Attentiveness to the concepts that drove the relevant thought paths will permit tracing the evolution of human thought. Additionally, this approach will provide many worthwhile sources and foster the emergence of an enduring theory about the nature of profound knowledge that leads to making better organizational decisions.

3.4 Thinking Pathways for Investigation

Just as the pursuit of scientific knowledge and its application to industrial management accelerated the economic development of mankind in the last century, the failure to develop a coherent approach to profound knowledge is likely to block the more universal application of critical managerial lessons by the executive function in the coming century. The current state related to a theory of profound knowledge will be demonstrated by tracing the evolution of thinking pathways that emerged historically and advanced the scientific method, statistical reasoning, elements of profound knowledge, and the coherent pursuit of quality.

The grounded research method applied in this dissertation will pursue distinctly different, but interrelated, thinking pathways. These will be based on the answers to questions that were initiated in the late 1800s as the industrial revolution began its pursuit of thought clarity. Those questions were stimulated by others that Peirce (1878) had asked earlier. This research methodology uses the grounded theory approach to investigate historical contributions that were intellectual precursors to the concept of profound knowledge. Grounded theory uses a framework for the generation of concepts, reducing categories of interest and identifying their unique properties. These categories and associated properties produce a “eureka” type discovery which becomes a building block for the emergent substantive theory (Glasser, 1998, p. 133).

Specifically, this dissertation will assess the six thinking pathways that formed the basis of the theory of profound knowledge that is shown in Figure 11. It will describe the evolution of the mental models that define those categories, based on a variety of perspectives that Deming integrated implicitly when he formulated the system of profound knowledge. In particular, these evolutionary mental models, paradigms, or thinking pathways include progressive shifts related to belief, science, probability, systems, quality, measurement, learning, and strategy. They emerged during the preliminary research regarding the dialog between Shewhart and Deming and are described below:

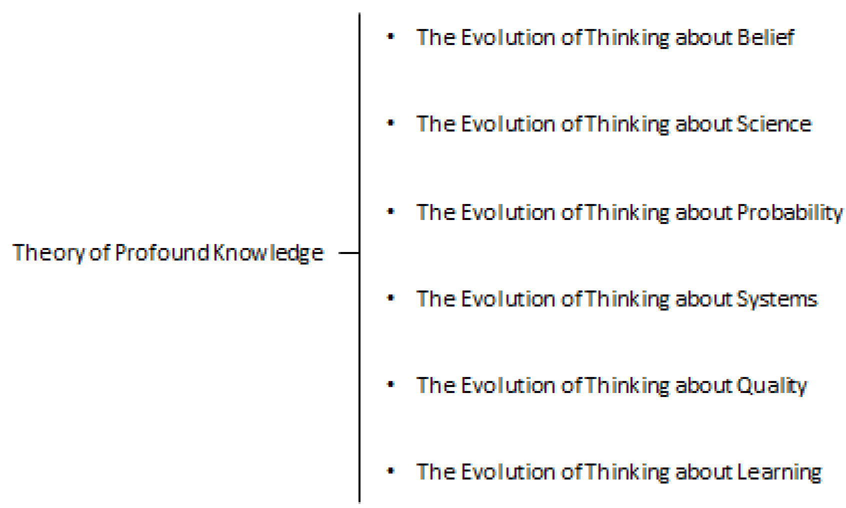

FIGURE 11: Thinking Pathways in Pursuit of a Theory of Profound Knowledge

How did these six thinking pathways emerge? What should be considered in the study regarding their roots and development?

3.4.1 Belief

This thinking pathway evolved from the early articles that occurred between Peirce (1877), William K. Clifford (1877), and William James (1890) in the late 1880s. During that era, psychology and philosophy separated into distinct disciplines, and a focus was placed on scientific philosophy beginning with discussions of logical positivism and its search for the meaning of knowledge through the foundations of mathematics.

3.4.2 Science

Clifford's essay (1877) evoked an explosion of interest in the metaphysics of science and philosophy of science in the late 1880s. Einstein's (1936) use of thought experiments for discovery of the theory of relativity in 1905 opened a new era of physics and changed the way that scientists would pursue the development of knowledge in their fields.

3.4.3 Probability

John Maynard Keynes' book, *Treatise on Probability* (1921), coupled with Percy W. Bridgman's book, *Logic of Modern Physics* (1927), heralded a more pragmatic usage of probability analysis and moved statistics into the mainstream of scientific methods.

3.4.4 Systems

Alfred North Whitehead's book, *Process and Reality* (1929), laid the cornerstone for process philosophy and the interest in developing more comprehensive systems for explaining and understanding the nature of reality.

3.4.5 Quality

Walter Shewhart advanced quality thinking with his book, *The Economic Control of Quality of Manufactured Products* (1931). It was the fountainhead of quality thinking for decades to come.

3.4.6 Learning

Beginning with John Dewey's book, *How We Think* (1910), and concluding with his book, *Knowing and The Known* (1949), reflective thought advanced from introspection toward a more insightful way of educating; it resulted in the development of learning theory as a branch of psychology.

These thinking pathways provide the structure of the historical research that will be conducted.

This grounded research approach will be detailed in Chapter IV, and the emergent theory of profound knowledge will integrate the thoughts associated with these paths.

3.5 Desired Outcomes From the Inquiry

This dissertation research seeks to establish a theoretical foundation for a new paradigm—specifically one that is founded on a theory of profound knowledge based on the Bayesian moment model. That model will be developed in order to support human inquiry and aid transformative decision making by the executive function, which has the power to make choices and guide the future directions of their organizations. Specifically, the expected outcomes of this study will be achieved by advancing managerial thinking based on the following analytical objectives:

3.5.1 Developing a Comprehensive Theory of Profound Knowledge to Transform Common Cause Variation in Organizational Systems

This development will extend the structure Deming proposed in his system of profound knowledge related to the control of special cause variation in processes.

3.5.2 Developing Operational Definitions That Support the New Theory of Profound Knowledge

Those definitions will include a set of composite categorical features and their associated unique properties. They will distinguish between profound knowledge and its logical opposite, called "profane knowledge."

3.6 Research Methodology

This inquiry focuses on the proposed research questions, conducting qualitative inquiries that have been proposed in order to obtain actionable conclusions based on the available data. As

Glasser noted in his description of grounded theory, everything observable in a research domain should be considered as data, as follows:

> ...whatever the source, whether interview, observations, documents, in whatever combination. It is not only what is being told, but how it is being told and the conditions of its being told, but also all the data surrounding what is being told. It means that what is going on must be figured out exactly to determine what it is to be used for, that is conceptualization, not for accurate description. Data is always as good as far as it goes, and there is always more data to keep correcting the categories with more relevant properties (Glasser, 2001, p. 145).

This iterative process creates a sense of uncertainty and ambiguity in grounded research.

> The grounded theory researcher must feel comfortable with uncertainty, ambiguity, and confusion that come initially and during the various stages of grounded theory for brief periods. He must trust that uncertainty, ambiguity, and confusion are a useful path to becoming open to [theory] emergence (Glasser, 1998, p. 44).

The data that will be used in this dissertation is the literature that has been published to explain the evolution of thought in each of the specified thinking pathways. The method of historical analysis will be followed, considering the sources in publication sequence. Linkages among the ideas will be developed based on the claims of authors and convergent ideas, based on comparisons of writings proposed by the dialog participants. This approach will be used to determine which sources can be considered to be settled ways of thinking and accepted mental models. Glasser (1998) “describes this experiential approach, as follows:” (p. 102)

> Grounded theory is based on a third-level conceptual perspective analysis. The first level is the data. The second level perspective is the conceptualization of the

> data into categories and properties. The third level is the overall integration through sorting in a theory (Glasser, 1998, p. 136).

A grounded theory investigation develops fundamental comparisons by evaluating "conditions, contexts, consequences, covariances, contingencies, and causes" (Glasser, 1998, p. 137).

3.7 Evaluating Research Validity

Research validation connects a proposed conceptual model that emerged from a grounded research study with the empirical data observed in the experiences of subject matter experts. It evaluates the goodness of fit, workability, relevance, and modifiability (considered to be the ability to extend or adapt the model). These criteria were suggested by Glasser who noted that this approach "seeks to determine what is going on" (Glasser, 1998, pp. 18, 91). A questionnaire will be designed and distributed to an expert panel to fulfill this phase of grounded theory. The expert panel of academics and practitioners will be asked to compare and contrast the emergent model for the theory of profound knowledge. The academics will be selected from members of the International Academy for Quality, a peer-recognized professional group that is the apex of the quality profession, consisting of only 128 active members. The set of practitioners will be selected from qualified Lean Six Sigma Master Black Belts who have practiced in their fields for at least five years. A demographic summary of the individuals responding to that survey is reported in Appendix A along with relevant information regarding the survey and its administration. As Glasser commented, quantitative verification is not possible for a grounded theory; however, validation among an appropriate community is possible if the assessors possess characteristics that are relevant to the subject (Glasser, 1998, pp. 102-105). The resultant responses will be combined using phenomenological and heuristic interpretation to make a comparison of and to draw conclusions about the proposed theory. The survey and its administration will be discussed further in Chapter VI of this dissertation.

CHAPTER IV

THINKING PATHWAYS TOWARD A GROUNDED THEORY: THE INTELLECTUAL EVOLUTION OF A THEORY OF PROFOUND KNOWLEDGE—HISTORICAL ANALYSIS OF DOCUMENTARY DATA

Contemporary thinking about "profound knowledge" has ancient roots. Since the earliest recorded times man has pursued gaining understanding of the world around him and pursued an inquiry into nature and sources of knowledge about the universe in which he exists. Belief systems defined those things beyond the knowledge of man; however, those aspects which defined settled knowledge were identified as science and then dissected in ever smaller slices; and studied in more and more detail in the pursuit of ever more knowledge. This search to understand and explain the meaning of life through a formal process of inquiry began with Aristotle (circa 300BCE) when he wrote the *Organum* and *Rhetoric* (Aristotle, 2007; Aristotle, 2007; Aristotle, 2007; Aristotle, 2016; Aristotle, 2007; Aristotle, 2007). The next significant breakthrough occurred when Sir Francis Bacon (1878), who lived from 1561 to 1626, redirected the thoughts of Aristotle in his *Novum Organum Scientiarum* which focused on reduction as the method for obtaining true knowledge and thereby created a foundation for the conduct of modern scientific inquiry by distinguishing between the theoretical and empirical components of knowledge. David Hume (1888), who lived from 1711 to 1776, focused thinking on the idea of the criteria for knowing and his scientific approach was evaluating the evidence that it examined, and, in doing so, he contributed a methodology called empiricism which has evolved into the modern approach to science. Discussions about empiricism became more focused after the stimulation of intellectual thinking that occurred in parallel with the industrial revolution in the late 1700s and early 1800s and Charles Sanders Peirce (1908), who lived from 1839 to 1914, helped to concentrate thinking on the nature of the systems of belief and the need to assure that the results could be practically applied for future knowledge and thereby defined pragmatism, or as it was known during its early days, objectivism. Peirce (1908) proposed that the scientific method was appropriate for application as an epistemology for investigation of philosophical questions based on three modes of argumentation: abductive genesis of theory, deductive application of theory to determine its practical meaning and inductive testing of the utility of the theory for prediction of the utility of future experience–an earlier version of the Bayesian Moment Mental Model (pp. 90-112).

From this point of time onward the nature of objective observation was pursued vigorously to understand how man could control new knowledge as a means to create greater prosperity and advance the knowledge and well-being of mankind. A contemporary of Shewhart's, Charlie Dunbar Broad (1923), who lived from 1887 to 1971, provided more illumination into the way this evolution in thinking transpired and also described its reduction in a critical taxonomy to define how these thinking processes had been separated to accommodate more logical inquiry.

In the time of Francis Bacon, the subject of philosophy was a principal program of study in college and universities with specialization available in natural philosophy (roughly speaking logic and science) and moral philosophy (roughly speaking ethics and metaphysics). In Broad's 1923 book *Scientific Thought* (Broad, 1923), he described the relationship between scientific thinking and philosophic thinking. Broad (1923) stated that "the job of philosophy is to test beliefs" (p. 18). He made an observation that beliefs evolve over time and that "our final belief [will] differ in content from our original one, it will also differ in certainty" (Broad, 1923, p. 14).

According to him, the job of philosophy is to deal with “vague and unanalyzed concepts. We also have a number of uncriticised beliefs, which we constantly assume in ordinary life and in the sciences… All such beliefs call for criticism” (Broad, 1923, pp. 19-20). This is the job of epistemology. Broad decomposed epistemology into a structured taxonomy possessing two approaches to inquire about human reason: speculative philosophy and critical philosophy (see Figure 12 below which graphically illustrates a model that Broad presented in textual format). Broad (1923) commented that “philosophy is concerned with not with remote conclusions, but with but with the analysis and appraisement of the original premises… exposing them to every objection that one can think of” (pp.19-20). He identified two types of philosophy: critical and speculative. Broad (1923) defined the first, critical philosophy as: “the analysis and definition of our fundamental concepts, and the clear statement and resolute criticism of our fundamental beliefs” (pp. 19-20). He described speculative philosophy: “whose object is to take over the results of the various sciences, to add to them the results of the ethical and spiritual experiences of mankind, and to reflect upon the whole” (Broad, 1923, pp. 19-20). Combined these comprise epistemology–the search for knowledge and understanding of its nature. This was the pursuit that Deming followed; however, without the clarity of Broad in distinguishing between these differing categories of thought.

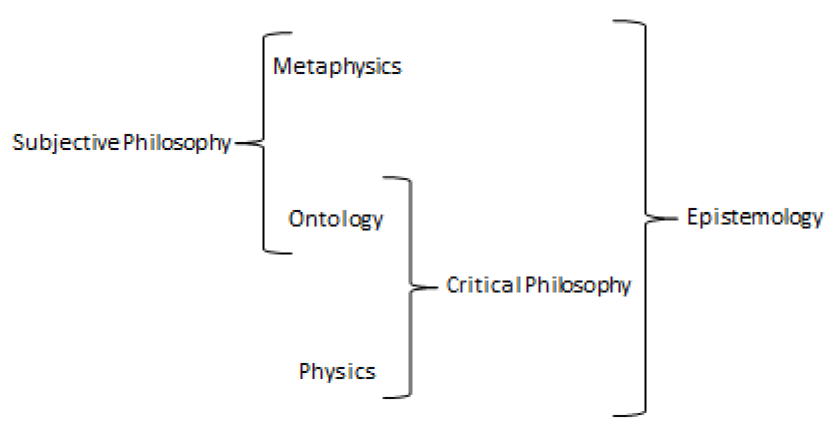

FIGURE 12: Division of Philosophical Inquiry According to Broad

The pursuit of “profound knowledge” by Deming has already been compared to Hegel’s idea of “absolute knowledge” but the distinction is that Deming focused on the aspects related to the critical philosophy described by Broad while Hegel ventured into the domain of speculative philosophy. Deming sought a transformation of organizations that would create a new state of their performance, at a higher, more effective level of operation which conformed to his idea of quality (Figure 13). While a speculative philosopher would focus on the nature of these events, Deming was concerned about how to guide the transformation into existence–probability as the basis of action.

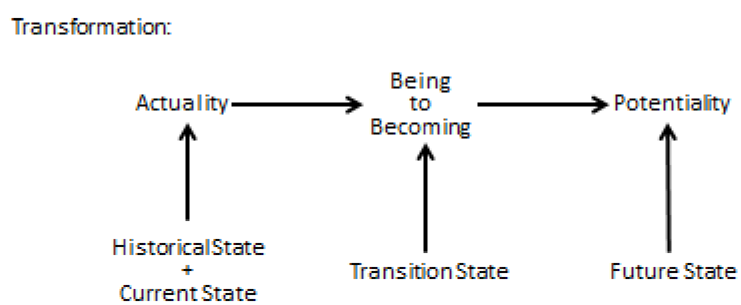

FIGURE 13: Transformation Process Creates new States of Reality

Broad’s book was one of those recommended by Shewhart for “further research” in his Appendix Three. The following grounded research that will be reported in this chapter of the dissertation pursues Shewhart’ suggestion and provides historical context for establishing the theory of profound knowledge. This evolutionary inquiry into the development of thinking related to the specific categories the system of profound knowledge that was created by Deming, attempts to answer the question: What could Deming have considered for inclusion in his system of profound knowledge if he had comprehensively pursued recommendations of Shewhart? This chapter demonstrates what ‘knowledge has been lost’ in current body of knowledge for quality thinking by failure to pursue Shewhart’s research agenda as interpreted through the lens of Deming’s system and then focused on the 'Bayesian moment' for understanding the mechanisms by which strategic executive decisions drive establishment and execution of change projects that achieve transformation in organizational processes.

The timeline for study consideration begins with the late 1880s as a century of progress in Industrial Revolution of basic industry matured into mass production enterprises and thought leaders of the day began to develop working theories about how to manage in the newly mechanized age. Beginning with essays in the late 1880s about belief systems and thinking processes the transformation of settled thinking was itself transformed over the course of the next century and these discoveries laid the foundation for what was to become a century of advances in knowledge of quality. This chapter will consider six "Thinking Pathways" that evolved into "The Theory of Profound Knowledge." It will describe the evolution of intellectual development in the mental models that define quality from a variety of perspectives and which were integrated into Deming's "System of Profound Knowledge." In particular, these mental evolutions or "Thinking Pathways" are the evolutions of thinking about: belief, probability, science, systems, quality, and learning. As man became more convinced of the settled nature of knowledge, then mental models that summarized past knowledge became formed to direct future inquiries, this is especially true in the evolution of mental models related to quality and it pragmatic application during and subsequent to the Industrial Revolution. Thus, the distinction drawn by Hume between theoretical and empirical knowledge and their value for the conduct of scientific inquiry will begin with the systems of belief that are the foundation of all knowledge systems as a means to understand their influence on the pursuit of profound knowledge by Shewhart and Deming.

4.1 The Evolution of Thinking About Belief

Shewhart developed his Theory of Control to address contemporary issues in the pragmatic pursuit of scientific knowledge as it applies to the production or manufacturing environment of his day. Shewhart's interest stimulated by an essay of Peirce (1878) on "How to Think Clearly" which originated a new generation of inquiry into the meaning of meaning and held implications for a multitude of academic disciplines (pp. 286-302). This essay extended a philosophic argument regarding epistemological relationships between belief, justified belief, and justified true belief and was initially poised by Clifford in 1877 and then later popularized by James in the last decade of the nineteenth century with his philosophical essay "The Will to Believe" (Clifford, 1877; James, 1896). Out of these intellectual seeds the philosophy of American pragmatism flourished and became a dominant driver of modern business, especially its quality thinking. These ideas formulated the framework for Shewhart's Theory of Control.

Herbert Spencer devoted the first 100 pages of his 1842 book, *First Principles* (Spencer, 1862), to what he called "the unknowables" and there he concluded that absolute reality or the ultimate truth is "unknowable" and that it will remain "unknown" because it is beyond the capability limits of human understanding. Thus began decades of debate on what can and can't be "known" and the relationship between scientific inquiry and the process of "knowing."

In his 1877 essay on "The Ethics of Belief," Clifford (1877) picked up the argument by stating:

> It is the sense of power attached to a sense of knowledge that makes men desirous of believing, and afraid of doubting…. No simplicity of mind, no obscurity of station, can escape the universal duty of questioning all that we believe. This sense of power is the highest and best of pleasures when the belief on which it is founded is a true belief, and has been fairly earned by investigation (p. 286).

Clifford (1877) concluded his essay with his famous statement: "to sum up: it is wrong always, everywhere, and for anyone, to believe anything upon insufficient evidence" (p. 300). To hold a belief means to be convinced in the validity of that belief which implies that one is very confident in the valid basis upon in which the belief is established. This argument was a precursor to that of Broad's definition of critical philosophy. If there is not enough time to do research or the research would be incapable of demonstrating the validity of the belief, then Clifford (1877) concluded that that person then "has no time to believe" (p. 309).

Clifford's rule of belief that the right to believe must be, in a sense, earned based on the quality of the evidence that is presented to the believer–he concluded that everyone who wants to make a statement of fact-based science has a duty of inquiry in order to relieve doubt and establish the truth of that knowledge.

Peirce replied to Clifford in his 1877 essay "The Fixation of Belief" (Peirce, 1877) and in his 1878 essay "How to Think Clearly" where he commented about the need for clarity.

> There can be no question that a few clear ideas are worth more than many confused ones…. A clear idea is defined as one which is so apprehended that it will be recognized wherever it is met with, and so that no other will be mistaken for it. If it fails of this clearness, it is said to be obscure (Peirce, 1878, p. 286).

Peirce (1878) opposed the idea of "belief" to the concept of "doubt:" "I use [the words 'doubt' and 'belief'] to designate the starting of any question, no matter how small or how great, and the resolution of it" (p. 293). He continues to describe three grades of clarity, or levels of understanding, which are related to his pragmatic logic as "clear and distinct ideas" and which frame the coming discussions in Shewhart about the importance of clarity in meaning as essential to obtaining scientific knowledge. The three grades of clarity identify by Peirce are required to gain a full understanding of a particular concept: (1) familiarity with it through a daily experience or encounter; (2) an ability to provide a general definition of it; and (3) knowing what consequences should prevail if the concept is true. Once this degree of clarity has been obtained then one can say to know something about it and can speak about it with assurance. This finding is the cornerstone of logical positivism, a philosophical movement which influenced thinking for the coming decades.

Karl Pearson wrote the *Grammar of Science* (Pearson, 1900) to clarify what is meant by scientific inquiry. Pearson (1900) commented, as follows:

> The duty of science does not end with showing an argument to be fallacious; it has to investigate the origin of the fallacy and show the nature of the process by which it has arisen…. The science of the future will replace knowledge by belief in the perceptual sphere, and will reserve the term 'knowledge' for the conceptual sphere – the region of their own (sic) concepts and ideas… A conception to have scientific validity must be *deducible* from the perceptions of the normal human being (pp. 52-54).

He commented that: "If the reader questions whether there is still war between science and dogma, I must reply that there always will be as long as knowledge is opposed to ignorance" (Pearson, 1900, p. viii). Furthermore, the relationship between the content of Pearson's "Canons of Legitimate Inference" and Shewhart's theory of control indicate that Pearson's ideas, which were known and referenced by Shewhart, serve as a direct precursor to the taxonomy that Shewhart offered for his theory of control and therefore it is linked to William Clifford's essay on "The Ethics of Belief" as the originating stimulant of this line of thinking. After referencing both Stanley Jevons Principles of Science and Clifford's essay on "The Ethics of Belief," Pearson states:

> We ought to notice that the use of the word belief in our language is changing: formerly it denoted something taken as definite and certain on the basis of some external authority; now it has grown rather to denote credit given to a statement on more or less sufficient balancing of probabilities. The change in usage marks the gradual transition of the basis of conviction from uncriticising (*sic*) faith to weighted probability. The canons we have

referred to are the following:

1. Where it is impossible to apply man's reason, that is to criticize and investigate at all, there it is not only unprofitable, but anti-social to believe. Belief is thus to be looked upon as an adjunct to knowledge, as a guide to action where decision is needful but the probability is not so overwhelming as to amount to knowledge. To believe in a sphere where we cannot reason is anti-social, for it is a matter of common experience that such belief prejudices action in spheres where we can reason.

2. We may infer what we cannot verify by direct sense-impression only when the inference is from known things to unknown things of the like nature in similar surroundings. Thus we may not infer an "infinite" consciousness outside the physical surroundings of finite consciousness; we may not infer a man in the moon, however like in nature to ourselves, because the physical surroundings in the moon are not such as we find man in here, etc., etc.

3. We may infer the truth of tradition when its contents are of like character and continuous with men's present experience, and when there is reasonable ground for supposing its source to lie in persons knowing the facts and reporting what they knew. The tradition that Wellington and Bücher won the battle of Waterloo fulfills the necessary conditions, while the miracle of Karl the Great and the adder fulfills neither condition.

4. While it is reasonable in the minor actions of life, where rapidity of decision is important, to infer on slight evidence and believe on small balances of probability, it is opposed to the true interests of society to take as a permanent standard of conduct a belief based on inadequate testimony. This canon suggests that the acceptance, as habitual guides to conduct, of beliefs based on insufficient evidence, must lead to the want of a

> proper sense of the individual's responsibility for the important decisions of life (Pearson, 1900, pp. 59-60).

The importance of these precursor writings to Shewhart's thinking becomes more obvious when it is observed that Shewhart inferred a reference to the justified true belief argument in his 1939 book:

> To every prediction there corresponds a certain degree of rational belief. It is necessary now for us to note more carefully than heretofore how knowledge differs from the original data and from predictions. Knowledge, as has been stated, begins in data and ends in other data. It starts with original data and makes predictions about data not yet taken, involving at the same time, something more–it involves a certain degree of rational belief in a prediction based upon evidence derived from the original data; this relationship between prediction and evidence is of great importance from the viewpoint of the presentation of the results of measurement as knowledge. It is perhaps not necessary to point out that just as soon as we begin to consider knowledge it is customary for us to introduce some kind of requirement of truth or validity for the predictions based upon the analysis of the original data. However, the fact is often lost sight of that there is an important distinction between valid prediction in the sense of a prediction being *justifiable* upon the basis of the available evidence and the accepted rules of inference" (Shewhart, 1939, p. 353). [Emphasis was in Shewhart's original text.]

Shewhart's statement of levels of control is reproduced here for ease of reference:

> ***Level 1:*** Belief that the future cannot be predicted in terms of the past
>
> ***Level 2:*** Belief that the future is pre-ordained.
>
> ***Level 3:*** Inefficient use of past experience in the sense that experiences are not

systematized into [predictable] laws [according to the method of science].

Level 4: Statistical process control methods are applied to a real world stream of process performance data to assure that it is able to achieve “control within limits.

Level 5: Engineering process control automates the statistical process control through the use of decision criteria for quality and feedback loops to control the process within limits to achieve “maximum control”–a state where only chance fluctuations in a phenomenon are produced by a constant system of a large number of chance causes in which no cause produces a dominating effect.

Level 6: Laws of science, knowledge of all laws of nature, exact science (Shewhart, 1939, p. 353).

Thus, Shewhart’s “Theory of Control” directly relates to the dialogs about belief and its role in developing scientific knowledge which had occurred in the prior decades (Table 3).

Type of Belief	Shewhart Levels in Theory of Control	Rational of Assignment for Shewhart’s Levels
Belief	Level 1, 2, and 3	Subjective Belief
Justified Belief	Levels 4 and 5	Based on Knowledge
Justified True Belief	Level 6	Based on Science

TABLE 3: Comparing Philosophical Belief Positions to Shewhart’s Theory of Control

However, the presence of knowledge also implies that the meaning of the deduction has been defined objectively rather than subjectively. Thus Shewhart became concerned with the concept of meaning and semiology and communicative behavior as it related to the process of analytical inquiry. Several of Shewhart’s contemporaries who have been previously cited also were discussing this topic: Bridgeman, Lewis, and Whitehead. This led Shewhart to specify a "Criterion of Meaning" in his 1939 book and also to illustrate the relationship between evidence and meaning (Figure 14 (Ogden & Richards, 1923, p. 11)). Shewhart also referred to the book, *The Tyranny of Words* by Stuart Chase (1938) in a footnote included in his 1938 book. Chase's work was based on a continuing dialog among contemporaries (Korzybski, 1933; Pareto, 1935; Planck, 1936). Chase observed that problems in meaning come from lack of clarity between objects and referents, an idea that he attributed to Charles K. Ogden and Ivor A. Richards (Ogden & Richards, 1946).

Ogden and Richards describe how to interpret this triangle in the following:

> Between the symbol and the referent there is no relevant relation other than the indirect one, which consists in being used by someone to stand for the referent. Symbol and Referent, that is to say, are not connected directly (and when, for grammatical reasons, we imply such a relation, it will merely be an imputed, as opposed to a real, relation) but only indirectly around the two sides of the triangle (Ogden & Richards, 1946).

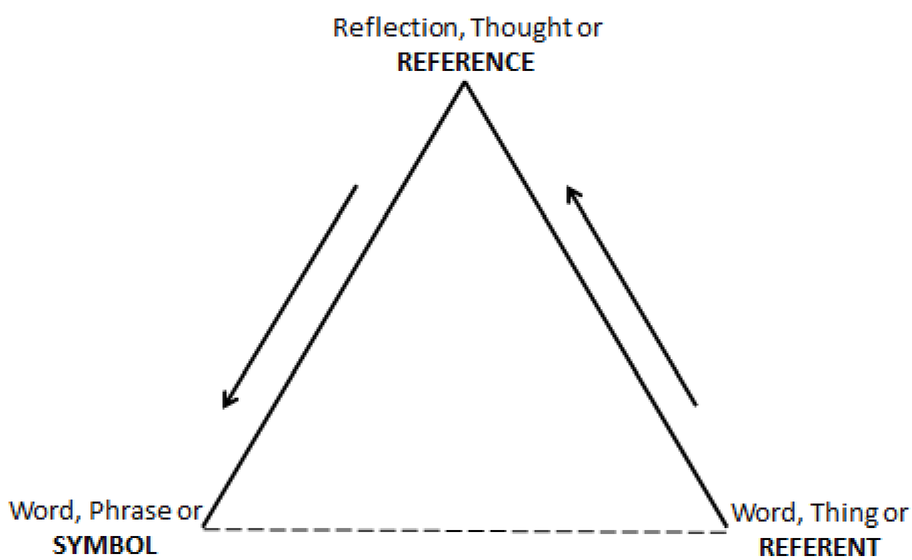

FIGURE 14: Triangle of Meaning

The problem in clarity of communication is that all too often people will hold that the "imaginary" relationship, illustrated by the dashed line in the model, is a state of reality and will not take the time to figure out what is meant. Chase (1939) commented that: "'Belief' in 'belief'… leads to fanaticism and dogmatism" (p. 63). This is the case when people describe a logically untenable or factually unsupportable position and refuse to doubt and question. "The student of semantics is embarrassed with the sheer richness of the evidence that people do not know what they are talking about" (Chase, 1939, p. 244). This situation leads to fanaticism and dogmatism which was later highlighted by Eric Hoffer in his 1951 book, *The True Believer* (Hoffer, 1951). "For those who believe, no proof is necessary. For those who do not believe, no proof is possible" (Chase, 1937, p. 125). However, Chase encourages putting away illusionary concepts that have no referent in reality but to embrace clarity in communication as a basis for understanding: "We are done with rigid principles that exist only in the brain" (Chase, 1938, p. 250)

Shewhart had identified that there are "two distinct uses of language: (a) to communicate information or knowledge; and (b) to arouse an emotional attitude in a reader or influence his action in any way other than by the information transmitted. These two uses of language… are referred to as the *scientific* and *emotive* respectively." This is similar to the distinction that was drawn by Kahneman when he described two distinct thinking systems: Thinking Slow (rational or "System 2") and Thinking Fast (emotive or "System 1"). Scientific data observations require interpretation and analysis of the states of being that have been perceived and processed; however, making predictions regarding future expectations needs metaphysical projection of things that are yet to be. "Every meaningful interpretation involves a prediction" (Shewhart, 1939, pp. 84, 92).

Empiricist Hume (1748) commented: "The wise man, therefore, proportions his belief to the evidence" because "there is no such thing as Chance in the world; our ignorance of the real cause of any event has the same influence on the understanding and begets a like species of belief or opinion." There is no settled science as "all knowledge degrades into probability" (Hume, 1748)

The dialog regarding belief, meaning, semiotics and semantics developed the philosophy of science emphasis on linguistics (see Table 4) has been documented in the following publications:

Author(s)	Source Information	Primary Contribution
David Hume	1739, *Treatise on Human Nature* (London: John Noon)	Examined the psychological state of nature and the belief that passion is the psychological basis of human nature but that all human knowledge is the result of experience
William K. Clifford	1877, "The Ethics of Belief," *Contemporary Review*, 29:2, 289-309	Argued against belief as blind faith that "it is wrong always, everywhere, and for anyone to believe anything upon insufficient evidence."
Charles S. Peirce	1877, "The Fixation of Belief," *Popular Science Monthly*, (November) 12: 1-15	Opposed the idea of "belief" to that of "doubt" which he designated as "the starting point of any question"
Gotlob Frege	1892 (German), 1952 (English), "On Sense and Reference," *Philosophical Writings* (London: Blackwell), 25-50	Indicated that a singular term may be used in two ways: reference is the proper name for the object while sense expresses the thought or the perception that it invokes

George E. Moore	1899, "The Nature of Judgment," *Mind*, 8:30, 76-193	Commented that the difference between empirical and a priori statements is in the nature of the judgments – only existential types of statements can be empirical
George E. Moore	1903, *Principia Ethica* (Cambridge: Cambridge University Press)	Described the term "good" and the idea of "goodness" as indefinable as the knowledge of values cannot be derived from the knowledge of facts
Alexius Meinong	1904 (German), 1962 (English), "The Theory of Objects," *Realism and the Background on Phenomenology*, Chisolm, Roderick, editor (New York: The Free Press)	Described objects as having one of three modes of being: existence, subsistence or "abstinence" which is actually a mode of non-being and all objects can have four classes of psychological acts: representation, thought, feeling and desire
Bertrand Russell	1905, "On Denoting," *Mind*, 14:5, 479-493	Described "a denoting phrase" as a noun that is preceded by a quantifier and predicated by a qualifier
John Dewey	1910, *How We Think* (New York: D. C. Heath)	Introduced the idea of "reflective thinking" and logical mechanisms for making human judgment based on the logic of Jevons and Mill
Ludwig J. J.	1921, *Tractatus Logico-Philosophicus* (London: Keegan Paul)	Presented a series of self-evident

Wittgenstein		statements which defined the core principles of logical positivism and ended with the statement regarding belief "whereof one cannot speak, thereof one must be silent"
Bertrand Russell	1921, *The Analysis of Mind* (London: George Allen and Unwin)	Cited by Shewhart – Described how the mind operates in terms of sensations, memory, words and meaning, and perceptions of truth and falsehood
Clarence I. Lewis	1929, *Mind and the World Order: Outline of a Theory of Knowledge* (New York: Charles Scribner's Sons)	Cited by Shewhart – Described what he called a conceptualistic pragmatism in a theory of epistemology and knowledge begins with a sensuous given as it's a priori and ends in experience
Alfred Korzybski	1933, *Science and Sanity: An Introduction to Non-Aristotelian Systems and General Semantics*, 2nd edition (Fort Worth: Institute of General Semantics)	Described that humans are limited by the structure of their nervous systems and the structure of their languages as humans do not experience the world directly but by abstract perception that is difficult to explain linguistically
Maurice Merleau-	1945, *Phenomenology of Perception* (Paris: Editions Gaillmard)	Described the body as a perceiving

Ponty		thing that is “engaged” with the phenomena which is a combination of the body’s sensory-motor functions and the object itself
Peter F. Strawson	1950, “On Referring,” *Mind*, 59:235, 320-344	Criticized Russell in “On Denoting” for classifying as “false” statements about things that do not exist and that one needs to know the use of a word in order to understand its meaning

TABLE 4: Publications Related to the Philosophy of Science Emphasizing Linguistics

4.2 The Evolution of Thinking About Probability

Shewhart (1926) noted in his early writing, as he investigated the subject of measurement, that “every measurement is subject to error” (p.12). One means to cope with these errors is through taking averages of sampled data to answer the question: “What is the most probable value?” (Shewhart, 1924, p. 53). This section of the chapter will consider how lessons learned in the development of statistical thinking have influenced Shewhart’s thinking and this impact on Deming’s System of Profound Knowledge. The section begins with consideration of the various types of probability that relate to the states of belief found in observations of data and moves on to discuss how distributions of data operate in reporting and analyzing data. Finally, this section will describe the information theory approach to measurement which begins with the premise that all data are inexact and thus statistical in nature. Measurement is therefore a way to observe phenomena and taking a set of measurements reduces uncertainty in the degree of knowledge about the actual entity.

- Probability as the Basis for Science: Probability theory evolved out of the examination of games of chance where all of the possible logical outcomes were considered to be equally likely (Keynes, 1921; Laplace, 1814; Savage, 1954; Venn, 1866; Whitehead, 1929). But games of chance have a limited number of fixed outcomes and this model does not adequately represent the real-world situation in which a specific action must be chosen based on observed (messy measurement) data and expectations for future performance. To quantify the model of "The Bayesian Moment" it is necessary to summarize observations of hindsight data and project to the foresight expectations. The means to summarize the past observations is statistical distribution theory; the means to anticipate the future expectations is probability theory; and the means to cope with the messy data to identify profound knowledge is information theory. However, distributions are expressed in probabilities, perhaps starting with a survey of the impact of probability and its role to belief systems is a better place to begin this survey. Table 5 (de Elia & Laprise, 2005, pp. 1130-1132) summarizes the development of probability theory over time:

	Classical Theory	Frequency Theory	Subjective Theory	Propensity Theory
Theoretical Basis	Principle of Indifference	Frequency of Occurrence	Degree of Belief	Causal Connectivity
Conceptual Basis of Theory	All options are equally likely	Reference to the class of facts	Insight from Intuition and Knowledge	Current State of Development
Philosophical Foundation of Theory	Conjectural	Empirical	Subjective	Metaphysical
Problems with	Ambiguity in the	Reference Class:	Unbridled	Disputed

the Theory	Principle of Indifference	Problem Defining Logical Categories	Opinions Without Objective Verification	Conceptual Basis
Theory Proponents	Jacob Bernoulli Pierre-Simon Laplace	John Venn George Boole Carl Gauss Richard von Mises	Thomas Bayes Bruno de Finetti Leonard Savage	John Maynard Keynes Charles S. Peirce Karl Popper

TABLE 5: Epistemological Interpretations of Probability Theory

While Bridgeman, in *The Logic of Modern Physics* (1927), provided a probability paradigm for Shewhart's "boundary conditions of performance," John Maynard Keynes, in *A Treatise on* Probability (1920); Alfred North Whitehead, in *Process and Reality* (1929); and Leonard Savage, in *The Foundations of Statistics* (1954), offered other interesting insights. However, other than referencing the first two of these books there is no evidence that Shewhart's thinking was at all influenced by their ideas. The views of the other three authors regarding probability theory are more germane to the current discussion for understanding how probability theory relates to the work of Shewhart.

Whitehead's ideas feature the best transition from the belief-based dialog of the chapter's first section. Whitehead (1929) asked the opening question: "What is there in the nature of things, whereby an inductive inference, or a judgment of general truth, can be significantly termed 'correct' or 'incorrect'?" (p. 199). He immediately provides an answer: "On the evidence before us our beliefs are justified, provided that we introduce into our judgments some estimate of the high probability which is all that we mean to affirm" (Whitehead, 1929, p. 200). Our estimates of the high probability must also admit that "some margin of uncertainty exits" (Whitehead, 1929, p. 201). Thus, Whitehead (1929) identifies the problem that the idea that "the belief [in] statistical probability is itself probable" (p. 201). How to cope when, as Whitehead (1929) observes: "Our conscious experience involves a baffling mixture of certainty, ignorance and probability" (p. 205)? Whitehead discusses four aspects of statistical theory which are problematic for probability (this is the case where quality of an actual entity must be evaluated and in which Shewhart (1931) expressed an interest in investigating the nature of an actual entity as a quality characteristic (p. 486)):

(1) "Probability is always [judged] relative to evidence; so on the statistical theory, the numerical probability will mean the numerical ratio of favorable to unfavorable cases in the particular class of 'cases' selected as the 'ground' for statistical comparison. But, alternative 'grounds' certainly exist. Accordingly we must provide a reason, not based upon 'probability' why one 'ground' is selected rather than another" (Whitehead, 1929, p. 201). In this argument, Whitehead points out that any conclusion about probability is based on the "goodness" (e.g., 'grounds') for classification of the actual entity that is being judged as 'favorable' (meeting requirements or 'good') and 'unfavorable' (not meeting requirements or 'bad'). As he comments – there are always other ways to make a quality judgment and various 'grounds' for judging quality may be used.

(2) The second item that Whitehead discusses has to do with the nature of the 'ground' and its probability: "The Primary requisite for a 'ground' suitable for statistical probability seems itself to appeal to probability. The members of the class, called the 'ground,' must themselves be 'cases of equal probability,' some favorable and some unfavorable, with the possibility of limiting types of 'ground' in which all members are favorable, or all members are unfavorable" (Whitehead, 1929, p. 202). In this description the concept of the "cases of equal probability" must be identifiable without reference to

probability but with reference to an "actual entity" instead, a given fact or observable event through direct knowledge and there must also be equally objective knowledge of the set of conditions that distinguish between the "favorable" and "unfavorable cases."

(3) "Thirdly, it is another requisite for a 'ground' that the number of instances which it includes be finite" (Whitehead, 1929, p. 202). The theory breaks down if the number of "instances" is infinite.

(4) "Fourthly, the method of 'sampling' professes to evade two objections. One of them is the breakdown … when the number of cases in the 'ground' is infinite. The other objection, thus evaded, is that in practice the case in question is novel and does not belong to the 'ground' which is in fact examined" (Whitehead, 1929, p. 202). This means that a paradoxical point is reached as these four considerations do not deliver an unproblematic use of probability. Thus the paradox: "either … an inference is irrational, futile, useless; or, when there is justification, there is additional information." In other words, making a decision based on probability alone will never provide enough surety in a solution (Whitehead, 1929, p. 203).

Whitehead (1929) concludes from his dialog that: "our probability judgments are ultimately derivable from vague estimates of 'more or less' in a numerical sense. We have an unprecise intuition of the statistical basis of the sort of way in which things happen" (p. 206). It is worthwhile noting that Keynes (1921) comes to a similar conclusion in his inquiry into probability; however, it is not as clearly stated as by Whitehead (pp. 242-252).

Savage wraps up the discussion with reference back to Table 5 as presented in this section at the beginning. Savage more precisely deals with the topic of personal, or subjective, probability in a way that can be related to the dialog on "systems of belief" that occurred in the prior century. He begins by discussing the concept of a "statistical decision" in the following way: "'Statistical decision' reflects the idea that inductive inference is not always, if ever, concerned with what to believe in the face of conclusive evidence, but that at least sometimes it is concerned with what action to decide under such circumstances" (Savage, 1954, p. 2). He begins where the discussion with Whitehead ends – the need to make a choice to do something drives the use of probability in a pragmatic way. This is the essence of transformation – change must be made for the better. What I the most likely change that will create goodness? What should be done?

Savage (1954) reinforces the classification of probability theories presented on Table 5 and he identifies three views for interpretation or probability: "Objectivistic views hold that some repetitive events, such as tosses of a penny, prove to be reasonably close agreement with the mathematical concept of independently repeated random events, all with the same probability" (p. 3). Note that both classical and frequency theories of probability fall into this "objective" class. Savage (1954) defines subjective probability: "Personalistic views hold that probability measures the confidence that a particular individual has in the truth of a particular proposition" (p. 3).

Finally, Savage (1954) classifies the "Propensity Theory" or causal view of probability in a manner that illustrates a little bias toward this logical view: "Necessary views hold that probability measures the extent to which one set of propositions, out of logical necessity and apart from human opinion, confirms the truth of another. They are generally regarded by their holders as extensions of logic, which tells when one set of propositions necessitates the truth of another" (p. 3). However, in the end Savage (1954) endorses the "Personalistic view itself insists that probability is concerned with consistent action in the face of uncertainty" (p. 56).

This is interesting because the use of personal probability relates to the system of belief in terms as a likelihood estimator of a "plain belief" function. An experience has to be interpreted and studied in order for it to become understood and transition into knowledge. However, the initial perception is more than not, likely to be a personal noting of a phenomena and recording the experience as a "quasi-experiment" with the actual entity observed. As the intensity of experimentation increases it takes objective probability to establish a logical relationship that could be called "true belief" and it takes a causal relationship to classify the proposition as a justified true belief. Thus, more information is needed than is available in the 'sampled ground' for the observation. This leads toward a need to consider Bayes Theorem, distribution theory and information theory to discover better means to make judgments about reality in order to predict the future with some degree of probability – the desired outcome of Deming's "System of Profound Knowledge."

Rev. Thomas Bayes identified a logical construct to manage estimation of future probability based on the degree of certainty in its prior knowledge which can be interpreted either in an objective or subjective manner. In the subjective interpretation Bayesian probability describes probability in terms of the degree of confidence by which beliefs they express are held. The subjective Bayesian probability has all of the difficulties described by Whitehead as well as all of the difficulties of the Personalistic view of probability described by Savage. Therefore, the question arises: What can be done to improve the quality of this knowledge? This is a critical act that must occur in the Bayesian Moment. Is there some other source of knowledge that will help to develop a solution set to the problems noticed in the Bayesian Moment?

Complexity is added into Bayes Theorem because "a posteriori" events observed in history are "noisy" and represent "dirty data" that cannot be cleanly used in a "neat" probability distribution for the sake of a "statistical decision." The data distribution that is gathered as the set of historical data forms the a posteriori type of probability in a Bayesian Moment. Such a data distribution describes the observations of all the data from the past – both signal which represents the measurements of interest, and noise, spurious types of signals that come from measurement error, human error as well as misperceptions about the nature of the data or the problem. What can be learned by examining data distributions?

Data distributions describe long-term probabilities. Distribution data summarizes the observations for a specific measurement parameter that have been collected over a period of time. However, any analysis based on such long-term observations is not sufficient grounds from which to draw expectation for real-time action as it represents summary information without respect to the time dimension of the problem. The study of distributions begins in the first half of the 18th century as French mathematician Abraham De Moire (1756), who lived from 1667 to 1754, studied expansion of coefficients of the binomial distribution and first observed what is called the normal distribution in *The Doctrine of Chances*, a reference used by Bayes in development of his theorem on conditional probability. Others who were influential in developing normal distribution theory were Carl Frederick Gauss (1809), Pierre-Simon Laplace (1812), Karl Pearson (1905; 1920), and Ronald A. Fisher (1925). Stephen W. Hawking greatly admired the work of Laplace and celebrated his theory in a famous essay titled: "God does not Play Dice." Hawking commented: "Laplace held that because the world is determined, there can be no probabilities in things." Therefore, he drew the conclusion that "probability results in our lack of knowledge" (Hawking, 1999). However, Scottish Empiricist David Hume (1740) stated the basis for investigation is in the development of a clear understanding of probability as "All knowledge resolves itself into probability" (pp. 181-182). Profound knowledge evolves out of a scientific understanding of the sources and causes of variation, which is based on probability, so Hume is right: all knowledge degenerates into probability. Distributions summarize experience but they do not describe what happens in particular individual events. In actuality, distributions generally describe what would be expected to occur over a reasonable period of time. However, summary data is not always normally distributed!

Agner Krarup Erlang (1909), who lived from 1878 to 1929, was a Danish statistician and early telecommunications engineer. He is most noted for his observations of statistical distributions which created the basis for queueing theory and the understanding of what is commonly called a "long tail" phenomena in statistical distributions. His 1909 and 1917 papers (Erlang, 1909; Erlang, 1917) demonstrated that the Poisson distribution applied to communication of message traffic (information) as well as the losses due to waiting time. His formulation of this equation is known as the Erlang Distribution. This distribution characterizes events occurring independently at an average observed rate may be appropriately modeled as a Poisson process with waiting times distributed between event occurrences modeled using the Erlang distribution in which the "long-tail" represents the set of data that have taken a long time to arrive at the point of observation (Erlang, 1917). Thus, time series data will always be biased with short arrival times at one end of the distribution and the late arrivals at the other. Thus, Erlang's distribution has a shape that demonstrates a long tail toward the less desirable effect (e.g., toward the right when time is to be minimized and toward the left when the value is to be maximized).

Shewhart (1939) had observed that managing performance measurement is problematic and he advised analysts to act accordingly: "Original data plotted in order of production may provide much more information than is contained in the distribution" (p. i). Coping with the fact that data are not exact and that imprecision must be managed by using statistics to reduce uncertainty to a level of acceptability was another significant theoretical discovery that occurred at Bell Laboratories during the era of Shewhart.

- Information Theory Copes with Measurement Uncertainty: Ralph V. L. Harley (1928) first discussed the concept of "information" as measurable in 1928 and Claude E. Shannon (1948) turned this idea into "Information Theory" in his 1948 article in the *Bell System Technical Journal*. Information theory helps an analyst cope with the problem that Measurement "the correlation of numbers with entities that are not numbers" (Nagel, 1931, pp. 313-335) but objects in the real world, in all of their "messy ugliness." Harley's paper used the word "information" to refer to a measurable quantity, reflecting the receiver's ability to distinguish one sequence of symbols from any other, thus quantifying information as a decimal digit. Thus, data observations are not “exact science” and their imprecision must be a part of the scientific inquiry itself. Shannon’s paper introduced a qualitative and quantitative model of communication as a statistical process underlying information theory. He began his paper stating: “The fundamental problem of communication is that of reproducing at one point, either exactly or approximately, a message selected at another point” (Shannon, 1948, p. 623).

Scientific inquiry begins with a research hypothesis (an initial guess or “Theory Opinion”) and then it proceeds to reduce this uncertainty through observation and experimentation. In this way all measurements must be considered uncertain. Thus, instead of assigning a single, fixed value to any particular measurement, it is better to portray a measure as a representative range (e.g., a confidence interval) as a means to demonstrate uncertainty in measurements. This conclusion corresponds well with Shewhart’s use of “boundary limits” for time series measurements in his control charts.

However, information measurements may be either qualitative or quantitative and it is up to the interpretation of a receiver as to the interpretation of the message. A challenge in making communication more effective is the need to reproduce, as closely as possible, the meaning that is conveyed in a message that was generated by another. By this description measurement is the assignment of a numeric value to an observation in a way that reduces uncertainty in the transfer of information between the transmitter and recipient. This definition implies that there is no clear demarcation between an estimate and a measure, other than the degree of uncertainty. The basic unit of information theory is the decimal digit, which was called a Harley in honor of the early work by Ralph Harley, but this metric is better known today as a “bit”–the fundamental unit of computing information.

The dialog regarding statistical thinking has evolved over time as the areas of learning have progressed from its beginnings in probability theory to information theory (see Table 6) and this has been documented in the following publications:

Author(s)	Source Information	Primary Contribution
John Maynard Keynes	1921, *A Treatise on Probability* (New York: Macmillan)	Cited by Shewhart – Presented a view of probability theory that is related to variation of evidence as in probability bands rather than fixed relationships of data evidence with respect to logical hypotheses
Samuel I. Hayakawa	1941, *Language in Thought and Action* (New York: Harcourt)	Linked the relationship between human behavior and symbolic representation from a variety of disciplines, including cybernetics, to understand how people speak about what they do and how to distinguish between reports, judgments and inferences
Stanley S. Stevens	1946, "On the Theory of Scales of Measurement," *Science*, 103:2684, 677-680	Presented four scales as a way to interpret data and understand how to apply

		statistical analysis (nominal, ordinal, interval, and ratio scales)
Leonard J. Savage	1954, *Foundations of Statistics* (New York: Wiley)	Proposed a subjective basis for probability analysis based on vague interpersonal differences in addition to strictly objective and repetitive evidence
Ludwig von Mises	1962, *The Ultimate Foundation of Economic Science: An Essay on Method* (New York: Van Nostrand)	Presented a view of probability that countered the positivist viewpoint and based itself on the principle that things that are known to man come from the actions that they undertake
Francis J. Anscombe and John W. Tukey	1963, "The Examination and Analysis of Residuals," *Technometrics*, 5:2, 141-160	Presented a variety of methods to analyze residuals from the least-squares method using a mixture of methods – graphical and numerical
Francis J. Anscombe and Robert J. Aumann	1963, "A Definition of Subjective Probability," *Annals of Mathematical Statistics*, 34:1, 199-205	Presents a subjective utility loss function for action observations by rational human agents with general models of belief and expands ideas of

		Savage (1954) for three types of probability
David R. Cox and E. Joyce Snell	1968, "A General Definition of Residuals," *Journal of the Royal Statistical Society. Series B (Methodological)*, 30:2, 248-275	Presented a method for analysis of non-linear residuals based on computer-based analyses
K. Anders Ericsson and Herbert A. Simon	1980, "Verbal Reports as Data," *Psychological Review*, 87:3, 215-227	Introduced the use of verbatim (verbal or phenomenological) reports as data which became a precursor to textual analysis and search
David R. Cox and E. Joyce Snell	1981, *Applied Statistics: Principles and Examples* (London: Chapman and Hall)	Described strategies for analysis of statistical problems to gain scientific understanding of real world applications
K. Anders Ericsson and Herbert A. Simon	1985*, Protocol Analysis: Verbal reports as data* (Cambridge: MIT)	Provided an in-depth approach to the analysis of verbal reports as data for exploring cognitive processes that are self-reported
Bob E. Hayes	1994, "How to Measure Empowerment," *Quality Progress*, February	Presented a survey to measure employee empowerment with 14 questions which has been rated with Cronbach's Alpha of 0.94 for 667 respondents

Kai Kristensen and Anders H. Westlund	2004, "Accountable Business Performance Measurement for Sustainable Business Excellence," *Total Quality Management*, 15:5-6, 629-643	Presented a criterion for use in making judgments about the validity of process performance measures
Richard D. DeVeaux and David J. Hand	2005, "How to Lie with Bad Data," *Statistical Science*, 20:3, 231-238	Presented ideas about how bad data can distort accuracy and consistency of data mining and how to improve data quality
Jeroen de Mast and Albert Trip	2007, "Exploratory data Analysis in Quality-Improvement Projects," *Journal of Quality Technology*, 39:4, 301-311	Provided an updated approach to Exploratory Data Analysis as a three step process using a graphical analysis of data for hypothesis generation
Automotive Industry Action Group (AIAG)	2010, *Measurement Systems Analysis: MSA*, 4th edition (Southfield, MI: AIAG Press)	Described methods for analysis of the effect of variation in the measurement of objects due to measurement devices as well as observers taking measures
Gert H. N. Laursen and Jesper Thorlund	2010, *Business Analytics for Managers: Taking Business Intelligence Beyond Reporting* (New York: New York: John Wiley & Sons)	Demonstrated how to develop an information strategy for a holistic approach to analysis of data mining and use of business intelligence modeling
Necip Doganaksoy and	2012, "Getting the Right Data Up Front: A Key Challenge," *Quality*	Addressed data gathering, data

Gerald J. Hahn	*Engineering*, 24:4, 446-459	cleaning, and data quality issues for four different methods for data procurement to improve the integrity of data analytics
Joakim Juhl and Hanne Lindegaard	2013, "Representations and Visual Synthesis in Engineering Design," *Journal of Engineering Education*, 102:1, 20-50	Provided methods for applying data visualization for design engineering

TABLE 6: Publications Related to Statistical Thinking and Learning

Probability is the foundation for statistics and statistics is the tool of science. Both Deming and Shewhart were physicists and their interest in probability theory arose naturally as a basis for their applications of statistical thinking to the process of production control with a view to the prediction of future states of potential performance. However, using these first two aspects of evolutionary thinking an important distinction can be made between predicting performance and forecasting performance. Forecasting is a wider term and is based upon the cumulative understanding that is drawn from all belief systems operating as a whole and thus encompasses positions derived from belief (personal or subjective probability), justified belief (objective probability) and also justified true belief (causal or propensity theory). Thus, forecasting is speculative thinking about a future state based upon a common sense system of belief that is chaotically entangled with data to express an opinion. On the other hand prediction involves a form of extrapolation from a set of currently observed data to a future state. The data may be observed (e.g., in terms of raw data) or it may be unobserved (e.g., in patterns derived from observations of data but whose patterns are not evident in the data as it is noticed by an observer). While, the "residuals" of such analyses may contain viable information, it has not been able to be processed in a way (e.g., it is no detectable, measureable, or decipherable in such a way as to establish some degree of regularity which permits prediction.) This is why a scientific position remains only a statement of "settled knowledge" as "unknown, unknowns" may influence the statement of "probabilistic fact" once its nature is revealed by the discovery of new insight or observations that are not available at the time a conclusion is drawn. All of science is a tentative statement about reality that is based on such a probabilistic judgment. It is from this perspective that the physicists following Einstein began to pay more attention to the concepts of statistics and probability. Thus, it is natural that scientists and physicists, of this age in particular, should harbor an interest in the process of doing science – scientific thinking and its relationship to probability.

4.3 The Evolution of Thinking About Science

Shewhart's theory of control was also based on the concept of "bounded control" which was suggested by Bridgeman as it fit with Shewhart's implementation in the statistical control chart methodology. Bridgeman's 1927 book, *The Logic of Modern Physics*, is an important link between Shewhart and the developing scientific methodologies of the preceding decades.

Why did Taylor combine the ideas of "science" and "management" to create his concept of "scientific management"? The answer, in a word, is most probably: Einstein. Albert Einstein's 1905 discovery of the "Theory of Relativity" changed the way that scientists thought about nature. What did Einstein contribute to the process of scientific inquiry, according to Percy W. Bridgeman? Bridgeman (1927) observed that Einstein's contribution of the concept of relativity was extended to the very way that he gained knowledge, the process of thought experiments, and that he means of his discovery was as important as the nature of the discovery itself. In the process of conducting scientific inquiry: "no aspect of psychology or epistemology is without pertinence" (p. xi). Bridgeman (1927) continued, as follows:

> Our ideas of what external nature is will always be subject to change as we gain new experimental knowledge, but there is a part of our attitude to nature which should not be subject to future change, namely that part which rests on permanent basis of the character of our minds. It is precisely here, in an improved understanding of our mental relations to nature that the permanent contribution of relativity is to be found. We should now make it our business to understand as thoroughly the character of our permanent mental relations to nature (pp. 1-2).

Einstein's Olympia Academy was a reading group of friends established by Einstein in 1902 to study physics and philosophy in his apartment in Bern, Switzerland (Highfield & Carter, 1993, pp. 96-98). Einstein suggested that the group begin by studying Karl Pearson's book *The Grammar of Modern Physics* (Highfield & Carter, 1993, pp. 96-102) and they also read other books on philosophy of science including Henri Poincaré's *Science and Hypothesis* (Poincaré, 1905), John Stuart Mill's *A System of Logic* (Mill, 1843), David Hume's *Treatise of Human Nature* (Hume, 1739), and Ernest Mach's *Analysis of Sensations* (Mach, 1886). Stuart Chase (1938) remarked:

> Rest on this thought for a moment. Since 1905, when relativity was first announced… a gathering number of human beings have been thinking and communicating in way more sure, more powerful, than have any human beings before… Einstein separated the observer from the observed. He threw the ego out of physics. He derived a picture of the world relatively undeflected by the human senses (pp. 85-86).

Chase (1938) continued: "The scientific method is concerned with how things *do* happen, not how they *ought* to happen. Knowledge of the way things do happen, with no ifs, ands, or buts, allows us to deal more effectively with our environment" (pp. 85-86). The specific contribution of Bridgeman was to define the operational approach, about which Chase (1938) commented:

> [This] makes knowledge about the world outside no longer absolute, but relative. The operation is performed relative to some standard, say the gauge or the meter stick. Concepts emerge from these operations which are definite and verifiable. Another man can perform the operation and check the concept. Concepts, observes Bridgeman, must be constructible out of materials of human experience and workable within that experience. When concepts move beyond the reach of experience, they become unverifiable hypotheses. Knowledge advances when we find how things are related and in what order (pp. 90-91).

Physics is an exact science that manages relativity through probability. This is reminiscent of a quotation from Clarence I. Lewis that Shewhart used to introduce a chapter in his 1939 book: "…knowing begins and ends in experience: but it does not end in the experience in which it begins" (Shewhart, 1939, p. 80). Science begins with an observational experience and curiosity and it ends with the experience of profound knowledge and confidence. Einstein commented that: "Science is not just a collection of laws, a catalogue of unrelated facts. It is a creation of the human mind, with its freely invented ideas and concepts" (Einstein & Infeld, 1938, p. 294). Einstein continues as he related belief to the search for knowledge and interprets the motivation for the search function to discover truth within the Bayesian Moment and there by a linkage between science and profound knowledge:

> With the help of physical theories we try to find our way through the maze of observed facts to order and understand the world of our sense impressions. We want the observed facts to follow logically from our concept of reality. Without the belief that it is possible to grasp the reality of our theoretical constructions, without the belief in the inner harmony of our world, there could be no science. This belief is and always will remain the fundamental motive for all scientific creation. Throughout all our efforts, in every dramatic struggle between old and new views, we recognize the eternal longing for

understanding, the ever-firm belief in the harmony of our world, continually strengthened by the increasing obstacles to comprehension (Einstein & Infeld, 1938, p. 296).

Clarity of thinking, a step-by-step analytical approach, and a healthy dose of skepticism are built into the scientific approach to management of work and the purpose is a never-ending search for knowledge about the way that the world works. Perhaps for these reasons Deming applied a “scientific approach” for innovation and improvement as part of the transformation activity of management once “profound knowledge” had been discovered. This process of the pursuit of profound knowledge is a journey in the diagnosis of reality–the actual entities that form our experience in life. Contributions to advancing the “meta-thinking” about the process of doing science in the modern age (see Table 7) are listed below in chronological order:

Author(s)	Source Information	Primary Contribution
Herbert Spencer	1962, First Principles (London: William and Norgate)	The unknowable is not the realm of science, but development of the laws of the knowable whereby all phenomena can be established as laws of high generalization through a process of evolution
John B. Stallo	1882, *The Concepts and Theories of Modern Physics* (New York: Appleton)	Introduced the idea of concepts in physics which must be treated as provisional not as facts
Ernst Mach	1883, *The Science of Mechanics* (Chicago: Open Court Publishing)	The goal of science is to develop the simplest and most economical abstract description of facts to find connections within the universe

Ernst Mach	1886, *The Analysis of Sensations and the Relation of the Physical to the Psychical* (London: Open Court Publishing)	The object of science is to connect phenomena which are perceived through the senses and are then connected as individual attributes
Karl Pearson	1892, *The Grammar of Science* (London: Adam and Charles Black)	The scope of science is to ascertain truth in every branch of knowledge and there is no sphere of inquiry that is outside the legitimate field of science
Thorvald Nicolai Thiele	1903, *Theory of Observations* (London: Charles and Edwin Layton)	Introduced methods for reducing the influence of observation errors and introduced likelihood functions which were applied Fisher
Albert Einstein	1905, "On the Electrodynamics of Moving Bodies," Annalen der Physik, [1905] 17: 891-921; in *Collected Papers of Albert Einstein*, 2:23, 125-159	Introduced the Theory of Relativity: The laws of physics are the same for all observers in uniform motion relative to one another.
Thorstein Veblen	1906, *"The Place of Science in Modern Civilization," Journal of Sociology*, 11:5, 585-609	Knowledge of facts and development of that knowledge distinguishes the civilized culture from an undeveloped one? The culture of science is both impersonal and pragmatic
Albert De Forest	1912, *The Theory of Measurements* (New York: McGraw-Hill)	Cited by Shewhart – measurement

Palmer		error should be analyzed to discover errors in assumptions made about observations
Henri Poincaré	1913, *The Foundations of Science* (New York: The Science Press)	Cited by Shewhart – identified the hierarchical nature of sciences that each lower level must first be set or before proceeding to the next level (a theory of magnitude is needed before things can be measured) and there are four kinds of hierarchical hypotheses: apparent, natural, indifferent (or neutral), and verifiable
Charlie D. Broad	1913, *Scientific Thought* (New York: Harcourt, Brace)	Cited by Shewhart – demonstrated that psychological events occur and should not create "limiting principles" on scientific inquiry
Charlie D. Broad	1914, *Perception, Physics and Reality: An Inquiry into the Information that Physical Science can Supply about the Real* (London: Cambridge University Press)	Description of the assumptions that must be made for natural science to inform about the nature of reality and development of causal theory of perception
Charlie D. Broad	1916, "On the Function of False Hypotheses in Ethics," *International Journal of Ethics*, 26: 377-397	Promotes the belief that commonly held beliefs or "false hypotheses" do not imply truth that should be acted

		upon (if all lemmings go over the cliff does it mean that because you are a lemming you MUST go over it too?
Albert Einstein	1919, “Induction and Deduction in Physics,” *Berliner Tagblatt*; in *Collected Papers of Albert Einstein*, 7:28, 108-109	Observation leads to an intuitive grasp of essentials which leads to hypothesis and from a system of axioms conclusions are drawn by logical deduction.
Albert Einstein	1921, *The Meaning of Relativity* (Princeton: Princeton University Press)	The objective of science is to bring them to experience and coordinate our ideas into a logical system.
William S. Jevons	1924, *The Principles of Science* (London: Macmillan)	Cited by Shewhart – induction is not guided by fixed rules like deduction is; induction is guided by empirical observation
Alfred North Whitehead	1925, *Science and the Modern World* (Cambridge: Cambridge University Press)	To truly understand technological advances requires the knowledge of the contemporary, historical and cultural context of scientific discovery
Bertrand Russell	1927, The Analysis of Matter (New York: Harcourt Brace)	Cited by Shewhart – a philosophical basis for understanding the physics of relativity and quantum mechanics

Percy W. Bridgeman	1927, *The Logic of Modern Physics* (New York: The Macmillan Company)	Cited by Shewhart – Description of the logical foundations of physics that influenced Shewhart's development of control charts
Arthur S. Eddington	1929, *The Nature of the Physical World* (New York: Macmillan)	Cited by Shewhart –Demonstrated that the theory of relativity creates a challenge for scientists to obtain a better understanding of their own scientific domain and introduces his idea of "selective subjectivism"
Charlie D. Broad	1933, "Is 'Goodness' a Name of a Simple Non-Natural Quality?" *Proceedings of the Aristotelian Society*, 34: 1-12	Proposed that the connection between a judgment of "goodness" and its actual entity is contingent and known only empirically
Karl Popper	1934, *The Logic of Scientific Discovery* (London: Routledge)	Defined "critical rationalism" to identify his idea that scientific theories are by nature abstract and can be tested only indirectly according to their implications
Albert Einstein and Leopold Infeld	1938, *The Evolution of Physics* (New York: Simon & Schuster)	Science can only ascertain what is not what should be – judgments of all kinds are necessary
Percy W. Bridgeman	1959, *The Way Things Are* (Boston: Harvard University Press)	Description of the relationship between meanings, logic, probability,

		physical sciences, psychology and their social implications
Thomas S. Kuhn	1962, *The Structure of Scientific Revolutions* (Chicago: University of Chicago Press)	Argued against strict falsification as the solutions are far from a perfect fit to probability theory – instead scientists work in a series of paradigms or thought (conceptual) patterns that include theories, research methods, postulates, and axioms that create the "current standard" in any field.
Karl Popper	1963, *Conjectures and Refutations* (London: Routledge)	Proposed to have solved the problem of induction through the offering of a conjecture (e.g., null hypothesis) and its falsification (refutation) which then will confirm the alternative hypothesis.
Richard P. Feynman	1967, *The Character of Physical Law* (Cambridge: MIT Press)	Discussion of symmetry in physical laws, distinctions between past and future, probability and uncertainty from a quantum perspective and the pursuit of new laws.

TABLE 7: Publications Related to the Process of Doing Science in the Modern Age

Science investigates the interrelationships among elements within the natural systems of the world. Scientists have attempted to separate man and his human nature from the study of the universe, as commented by Broad (1923) in *Scientific Thought*:

> In psychology we deal with minds and their processes, and leave out of account as far as possible the objects that we get to know by means of them. In all the sciences except psychology, we deal with objects and their changes, and leave out of account as far as possible the mind which observes them (p. 24).

However, science always begins in supposition–establishing a proposition for investigation, and this originating source of inquiry is bound to the human nature of the investigator and his state of curiosity about the way things are. Once a systemic perspective is attempted, then it is not possible to eliminate any of the system's elements as a fair subject for an inquiry seeking to understand the nature of the whole and the interrelationships of its elements.

4.4 The Evolution of Thinking About Systems

In his influential book, *The Principles of Scientific Management*, author Frederick W. Taylor (1911) proclaimed that "in the past the man has been first; in the future the system must be first" (p.17); however, his way of working told a very different story. In Taylor's transformation of organizations he treated the people component as if they were only a "pair of hands" that toils as individuals to perform tasks of human labor with no innate intellectual contrition expected from them as individuals. In Taylor's testimony to a Congressional inquiry shows that the labor unions in his day were concerned about the "inhuman way" that labor was treated as a pair of hands under Taylor's (1912) system (pp. 117-118).

A different approach was taken in Japan by Kaoru Ishikawa. Ishikawa promoted preserving the value of people by engaging the whole person–challenging their heads and not just merely using their hands. This Japanese approach to work became the foundation of the Japanese style of management called Total Quality Control in the 1960s. In this approach people formed a holistic component of the system and work collaboratively to achieve the system outcomes in harmony with the management process (Ishikawa, 1985).

Another aspect of system innovation that occurred following Taylor was the way Whitehead (1929) considered how content of work delivered (e.g., the product or reality) and the process of working to deliver it are two separate types of actual entity. The same separation is seen in John Dewey's later distinction between the object that is known and the process of knowing that creates learning and that these two actually both discover their meaning in the transaction in which they are engaged:

> Both common sense and science are to be treated as transactions. The use of this name has negative and positive implications. It indicates, negatively, that neither common sense nor science is regarded as an entity – as something set apart, complete and self-enclosed; this implication rules out two ways of viewing them that have been more or less current. One of these ways treats them as names for mental faculties or processes, while the other way regards them as "realistic" in the epistemological sense in which that word is employed to designate subjects alleged to be knowable entirely apart from human participation. Positively, it points to the fact that both are treated as being marked by the traits and properties which are found in whatever is recognized to be a transaction (Dewey & Bentley, 1949, p. 185).

This dualistic division is observed in the decomposition of quality into both product and process components by integrating the Theory of Attractive Quality by Noriaki Kano, which defines the product quality characteristics, with the process for designing and implementing this set of quality characteristics in the Quality Delivery Model (Watson, 2012, 126-130).

Jay W. Forrester conducted a life-long study of complex systems, the way their processes worked and their modes of interoperability. He observed "the ubiquity of systems" by which he means "a grouping of parts that operate together for a common purpose" (Forrester, 1968, p. 1). Russell L. Ackoff expanded this idea from the mechanistic world to consider "human behavior as systems of purposeful events" which "does not come to us in a disciplined form" (Ackoff & Emery, 1972, pp. 7-8). However this human system does include "choice states" which create "individuality in the psychological systems" (Ackoff & Emery, 1972, pp. 15-33). How choices are made and how the system works as an integrative whole were studied over decades by Forrester and his team collected conclusions drawn from the decades-long MIT study of Systems Dynamics and which resulted in the definition of 32 principles of systems measurement and operation:

1. The feedback loop is the basic structural element of systems. A system is composed of a positive and negative feedback loop. Notice the circular nature of the feedback loops. Feedback loops are the building blocks of systems that are linked together to form more complex systems.

2. Levels and rates are fundamental to loop substructure. Just as feedback loops are the fundamental building blocks of systems, so levels and rates are the building blocks of feedback loops.

3. Levels and rates are not distinguished by units of measure. A variable may either be a rate of change or the achievement of a level of change (e.g., velocity which can be a rate of acceleration or the degree to which an object has accelerated).

4. Levels are accumulations (in calculus – integrations). Levels will accumulate the results of rates (system actions) over time (e.g., adults and children are levels in rates of birth and maturing).

5. Levels are changed only by their rates.

6. A feedback loop consists of two distinct types of variables, the levels (also called stocks or states) and the rates (also called flows or actions). Feedback loops cannot be constructed without them. These two variables are necessary and sufficient structure for representing a feedback system.

7. Levels exist in conservative subsystems. A conserved quality has the effect that it is never created or destroyed (within its system); it is only moved around (e.g., note that the level called 'inventory' in a factory system contains goods that are moved into the factory and goods that are moved out to customers. Goods are neither created nor destroyed within the level. The level has conserved quantities of goods).

8. There is a distinction between a variable created by integration and one that is created as a policy statement in the system. One way to distinguish between rates and levels is to observe what happens if the action is stopped. A rate will cease while a level will continue to exist.

9. Decisions are always within feedback loops. No matter what the nature of the decision, it is always embedded within at least one feedback loop.

10. Every equation must have dimensional equality – all terms must be measured in the same dimensions. Dimensional inequality indicates a faulty equation.

11. First order loops (one level with feedback) exhibit exponential behavior in time – either as growth or decay – as it approaches its highest value (e.g., sales diffusion or effect of compound interest).

12. Levels completely define current system state or condition. The value of rates can be calculated with levels and system equations.

13. Only rates change levels – a level does not change a levels. The value of a current level is computed by the rate of change (rates in and out of the level) and the previous value of the level. A level variable is computed by the change, due to rate variables, that alters the previous value of the level.

14. Levels connected within the same conservative subsystem have the same units.

15. The solution interval DT (solution interval, period of measurement, delta time or time steps) is the time period in which the level is changed by the rate. DT is multiplied by the current rate and then added to the existing level value to obtain a new subsystem state.

16. Simple, second-order negative loops exhibit sinusoidal oscillation.

17. Goal, observation, discrepancy and action create a system substructure. A policy or rate equation recognizes a local goal toward which that decision point strives, compares the goal with the apparent system condition to detect a discrepancy, and uses the discrepancy to guide action. Thus, the goal is the desired position, the observation is the present position, the gap is the discrepancy between desired position and observed position, the action taken is to change the rate and consequently change the position.

18. The decision on what action to take is dependent on the quality and quantity of information in the system.

19. Level variables and rate variables must alternate. If the system starts at a level variable then it must encounter a rate variable at its next flow in the loop.

20. Rate variables are in same units as level variables divided by time.

21. Higher-order, positive-feedback loops usually show exponential behavior. Exponential growth is the only stable behavior of these positive feedback loops. All other are unstable and only slight perturbations in the initial level will cause the behavior to destabilize into exponential growth.

22. Conversion coefficients are always identifiable in real-world systems to define how much change is required to balance the equation dimensionally.

23. The system condition must be known at the beginning of the simulation (levels and rates).

24. The time constant of a first-order loop relates rate to level (level divided by time constant equals rate).

25. Rates are not instantaneously measurable. A rate is change over time and requires an accumulation of observations over time.

26. Every system has a closed boundary. All interactions that are important to the behavior of the system must be included within the system boundary. The system structure that is responsible for the desired behavior (called the generator) must be included in the model.

27. Before starting a simulation, a set of conditions must be set for all levels contained within the model boundaries.

28. Information links connect levels to rates.

29. Conversion coefficients should be observable in real systems not factors or indices that are developed after-the-fact (e.g., a factor called productivity is a connector between the level of workers and the rate of work (units per hour).

30. Rate equations are decisions are based on available information, a rate equation is a policy that determines how decisions are made.

31. Auxiliary variables are information links that help formulate more easily understandable rate equations.

32. Levels change smoothly, but not instantaneously–there may be a delay in their response to the rate change.

Publications in the field of systems thinking and related topics (see Table 8) have been prepared for over 90 years and the follow represent the most influential in defining the systems approach to the interpretation of reality:

Author(s)	Source Information	Primary Contribution
Alfred North Whitehead	1929, *Process and Reality* (Cambridge: Cambridge University Press)	Cited by Shewhart – Introduced process as the act of becoming reality in the form of an "actual entity"
Norbert Weiner	1948, *Cybernetics: Or Control and Communication in the Animal and the Machine* (Cambridge: MIT Press)	Introduced the concept of feedback in man-machine self-regulating systems with applied stochastic control mechanisms
Norbert Weiner	1950, *Human Uses of Human Beings* (New York: Houghton Mifflin)	Distinguished between work of machines and knowledge work and the need for cooperative communication systems

William Ross Ashby	1956, *An Introduction to Cybernetics* (New York: John Wiley & Sons)	Laid the foundation for complex adaptive systems and the idea of self-organizing systems
Jay W. Forrester	1961, *Industrial Dynamics* (Cambridge: Productivity Press)	Applied computer simulation for understanding dynamic system
Ulric Neisser	1963, "The Imitation of Man by Machine," *Science*, 139, 193-197	Father of cognitive psychology introduced the multiplicity of thought required for machines to fully imitate human thought
Ludwig von Bertalanffy	1968, *General System Theory* (New York: George Braziller)	Created general systems theory to describe interacting open systems combining men with machines
C. West Churchman	1968, *The Systems Approach* (New York: Dell Publishing)	Applied mathematics to the real world using operations research and systems analysis
Jay W. Forrester	1971, *Principles of Systems* (Cambridge: Productivity Press)	Documented systems dynamics to demonstrate how structure and simulation determines behavior
Russell L. Ackoff	1971, "Toward a System of Systems Concepts," *Managerial Science*, 17:11, 661-671	Introduced the concept of systems as purposeful and

		applied this way of thinking to organizations
Russell L. Ackoff and Fred E. Emery	1972, *On Purposeful Systems* (New Brunswick, NJ: Transaction Publishers)	Expanded his ideas on purposeful systems to human social behavior
Thomas H. Davenport	1993, *Process Innovation: Reengineering Work through Information Technology* (Boston, Massachusetts: Harvard Business Press)	Recommended reengineering work processes through the use of information technology
Gregory H. Watson	1994, *Business Systems Engineering* (New York: John Wiley & Sons)	Broadened organizational design using systems engineering based on principles of learning
Thomas H. Davenport	1994, "Managing in the New World of Process." *Public Productivity & Management Review*, 18:2, 133-147	Conceptualized the business process management as a way to conduct organizations
Thomas H. Davenport	1998, "Putting the Enterprise into the Enterprise System." *Harvard Business Review*, 75:4, 121-131	Information systems must model all of the functions of business into a coherent system model
Nelson P. Repenning and John D. Sterman	2001, "Nobody Ever Gets Credit for Fixing Problems that Never Happened," *California Management Review*, 43:4, pp. 64-88	Demonstrated a systems model to analyze the process management approaches between working harder and working smarter

John D. Sterman	2001, *Business Dynamics: Systems Thinking and Modeling for a Complex World*, (New York, NY: McGraw-Hill)	This textbook demonstrates how to apply systems thinking in the dynamic application of complex systems such as business
Thomas H. Davenport	2005, "The Coming Commoditization of Processes," *Harvard Business Review*, 83:6, 100-108	Argues for process standards so an aggregate of processes may be integrated instead of treating the process variability independently
Donella H. Meadows	2008, *Thinking in Systems* (White River, VT: Chelsea Green)	Clarifies human thinking processes for understanding how systems operate

TABLE 8: Publications Related to Systems Thinking

The systems approach identifies the human dimension in the psychological engagement of decision making and proposes applies scientific measurement principles to understand the data patterns that make these systems more self-evident. And it is probably for these reasons that the consideration of psychology was built into Deming's System of Profound Knowledge.

4.5 The Evolution of Thinking About Quality

Some of Joseph M. Juran's thinking can help clarify the "Knowledge Pathway" necessary to transition from measurement data to profound knowledge. In Juran's (1995) breakthrough strategy he divided the journey into two components: the first he called a "Diagnostic Journey" and the second he called a "Remedial Journey" (pp. 99-154) (Tukey, 1977, pp. 1-3). These two journeys take different paths to achieve differing objectives. The "Diagnostic Journey" copes with “dirty data” and needs to structure a system that eliminates discoverable “special cause variation” and may apply exploratory data analysis as an approach rather than classical statistical analysis to get the process to a point of control. The second part of the journey is the “Remedial Journey” which uses “scientific data” to focus the inquiry into common cause variation which originates within the “common cause” system and requires a more rigorous approach as methods and principles of experimentation and confirmation analysis or more rigorous statistics. However, this knowledge pathway was not evident in the 1920s. So how did this pathway evolve from the earliest approach to quality using inspection-based control? The initial focus was to “start at the beginning of the journey with a “Diagnostic Journey” as John W. Tukey said: “Unless the detective finds the clues, judge or jury have nothing to consider. Unless exploratory data analysis uncovers indications, usually quantitative ones, there is likely to be nothing for confirmatory data analysis to consider” (Tukey, 1977, p. 3).

- Development of Western Quality Thinking: In the history of the development of quality thinking it is possible to observe that a ‘scientific’ approach to quality was taken during the early years of the modern quality movement (e.g., from the 1870s to the 1950s). In this context, the phrase ‘scientific approach’ means that emerging theories were developed to advance the ‘state of the art’ and then tested operationally to validate their applicability and utility (Neustadt & May, 1986). These theories were contributed by individuals who ‘built upon’ the prior knowledge contributed by their predecessors in the community of practitioners of the quality discipline to thereby create a coherent ‘body of knowledge’ (alternatively described as ‘an accepted collection of concepts, theories, ideas, and philosophies’) that define what is meant by ‘quality’ and then develop the methods, techniques and tools to support work practices for achieve this capability.

During this eighty year period scientific development of a coherent theory and methodology related to quality, advances emerged in three global regions: United States, Europe and Japan. However, European contributions to the development of quality thinking stagnated in the 1960s while during this same period the American contributions shifted to myopically focus on teachings of a relatively few individuals who were revered as ‘guru’s’ and whose dogmatic quality philosophies and principles were based largely on opinion and created independently of each other, thereby creating a competitive atmosphere for quality thinking rather than a more collaborative style which is characteristic of a truly scientific evolution in a specific academic discipline. Concurrently however, Japanese progress in advancing quality persisted in following a structured scientific method built upon the advances made by prior generations to evolve a coherent, systematic approach to continual improvement program that was highly visible and widely publicized called Japanese TQM (Imai, Akao, & Koura, 1992, pp. 33-44).

What were the discoveries in the early period of development (1877-1950)? How did the development of this unique Japanese method evolve after 1950? How have recent quality developments applied this knowledge in any sense that could be called “profound”? It appears to have been stimulated as a catalytic reaction to American practices in industrial management.

- Development of Inspection-Based Quality at AT&T and Bell Research Laboratories:

Perhaps the pivotal influence in the confluence of quality-related thinking was a physicist from Bell Laboratories, Walter A. Shewhart (1891-1967). Shewhart, and to some degree his student and ardent disciple W. Edwards Deming (1900-1993), were products of the quality movement that was initiated in the Bell Laboratories unit of the Western Electric Company beginning with founding of the company in 1877 (Miranti, 2005, pp. 39-72; Molina, 1998, pp. 693-695).

In 1903 Malcolm Churchill Rorty (1875-1936) wrote a research memorandum describing the application of the theory of probability to operational problems within American Telephone and Telegraph (AT&T) which marked a beginning in the use of probability and statistics for practical problems in the Bell System and in 1931, during his induction speech as President of the American Statistical Association, he connected the statistical discipline with modernization in the methods of science (Molina, 1998, p. 694; Rorty, 1931, pp. 1-10). Rorty's career contribution is just one indication of the way that AT&T focused on the application of the scientific method using probability and statistics to discover practical knowledge that could improve the performance of work. Since the founding of AT&T there had been a continuing development of maturity in quality practices:

- During the initial years of manufacturing at the Bell Telephone Company (1877-1882) its quality work in production operations "actively consisted of 'go, no go' testing in order to determine, through the use of meters, calipers, and test kits, whether a product's physical attributes fell within acceptable tolerance ranges" (Mirati, 2005, p. 45).

- Bell Telephone acquired Western Electric in 1881. In 1904 Western Electric had developed the Hawthorne Works to manufacture telecommunications components and it "became the focal point for the organizational absorption of … new thinking" such as "insights from the scientific and systematic-management movements" (Mirati, 2005, p. 48).

- By 1906 AT&T had reduced the reliance on its production foremen and had increased the capability of its headquarters engineering function under Rorty and its attention shifted to correcting performance problems by building an effective inspection function through "the effective integration of quality information flows between operating subsidiaries, headquarters and manufacturing" and discovered that this activity was "critical to the process as well" (Mirati, 2005, p. 46).

Between 1911 and 1915. "…economy and efficiency became important evaluative standards" (Mirati, 2005, p. 47) and in this drive for economy manufacturing was consolidated so that the Hawthorne Works in Cicero, Illinois, a suburb of Chicago, became the only production facility for Western Electric. In 1915 Western Electric became a wholly owned subsidiary of American Telephone and Telegraph (AT&T).

By the early 1920s. The "inspection branch, which accounted for about 12 percent of the plant workforce, assessed the quality of manufactures." It "reported to Western Electric's engineering division [in order] to preserve its independence from the [manufacturing] groups [that] it evaluated" (Miranti, 2005, p. 47). "One commentator estimated that the high product-rejection and rework levels at the Hawthorne plant accounted for about one-third of the entire work effort during the 1920s" (Miranti, 2005, p. 50).

The emergence of statistical quality control (1922-1927). The decade of the twenties was a period of great development that consolidated the concept of quality into a statistical framework which is observable as a timeline:

The motivation for Shewhart's work was highly pragmatic: to assure that the Western Electric company could produce telephones with uniformity, as Deming observed: "The aim of the Western Electric Company was uniformity, so that a telephone company that bought their product could depend on it. They advertised, 'As alike as two telephones.' They were sincere, putting forth their best efforts toward uniformity, but unfortunately nearly always making things worse. They were smart enough to realize that they needed help. The problem found its way to Dr. Shewhart" (Deming, 1994, p. 172). Shewhart studied past production performance to decide how to create uniform future performance.

At this time the Engineering Department of Western Electric consisted of a group of approximately 100 professionals who were divided into five sections which "extended the capabilities for specifying inspection practices, defining quality standards, performing quality surveys, addressing field complaints, and compiling and analyzing quality data" (Miranti, 2005, p. 53). The Systems Inspection Section was headed by George D. Edwards; the Theory and

Special Studies Section was headed by Walter A. Shewhart; and the Inspection Methods and Results Section was headed by Harold F. Dodge. Shewhart "believed that the nature of quality could be expressed in mathematical terms" (Miranti, 2005, p. 54). Dodge concentrated on translating "theory into practical methodologies that were useful for plant operatives" such as the development of sampling theory and the practice of acceptance sampling (Miranti, 2005, p. 55). The period from 1924-1926 was particularly productive for these two groups as the staffs of Shewhart and Dodge prepared over 100 technical papers on "a wide range of theoretical and practical problems dealing with the application of probabilities to manufacturing inspection" (Miranti, 2005, p. 55).

In 1922 George S. Radford (1881-1956) published an influential book *The Control of Quality in Manufacturing*" to describe the United States Navy's approach to manage an inspection-based quality system in a manufacturing environment. In this book he also speculated about ways to employ the properties of the "bell-shaped normal curve" but only for "inspection-data analysis" (Radford, 1922). Radford inspired both Dodge and Shewhart through this publication. In 1923 Dodge had expanded the learning about sampling and had introduced a "more efficient sampling technique for Western Electric" (Miranti, 2005, p. 56) as he developed tables for random sampling inspection (Miranti, 2005, p. 58). While Dodge focused on inspection and sampling theory Shewhart concentrated on how to represent information that was gleaned from these inspections to improve part quality and the efficiency of the production process.

During 1924 a shift occurred in the way that Bell Laboratories operated the Hawthorne plant and it became more tightly coupled than a research arm issuing ideas to consider and a hands-on approach was tried. Shewhart and Dodge had "tried to assist the inspection branch by transmitting memoranda from New York that dealt with both theoretical and applied aspects of probability theory. Nevertheless, the plant continued to experience difficulty in adapting theory to practice, prompting the supervisor of inspection development to request that Bell Laboratories become more involved” (Miranti, 2005, p. 58).

On May 16, 1924 Shewhart published a one-page paper which created a chart that became known as the control chart (Small, 1956; Barasalou, 2010). [Note that Joseph M. Juran (1904-2008) had joined the inspection division at the Hawthorne works in 1924 while Deming had an internship at Western Electric in the summer of 1924 as a doctoral student at Yale, but Deming reported first meeting Shewhart in 1927.] (British Deming Association, 1992; Deming, 1994; Juran, 1995)

During 1925 “the pace of learning [at the Hawthorne plant] accelerated when Edwards began to champion the use of the innovative control chart that Shewhart had created in the previous year” (Miranti, 2005, p. 59). In 1925 the Engineering Department of Western Electric transitioned into the Bell Research Laboratories (Pearson, 1973, pp. 164-179).

In addition to these statistical studies about quality in manufacturing, there were also psychological investigations ongoing within AT&T. The Hawthorne works was turned into a laboratory for research into methods for improving productivity and quality in the human contribution to efficiency in the process of manufacturing. Harvard psychologist G. Elton Mayo (1933), who lived from 1880 to 1949, and industrial researcher Fritz J. Roethlisberger (1939), who lived from 1898 to 1974, partnered with Bell Labs and the National Research Council's Division of Engineering and Industrial Research to conduct a series of large scale experiments on the impact of illumination and worker motivation on productivity at the Western Electric Hawthorne Plant during the period 1924-1932 under the supervision of William J. Dickson (1939), who lived from 1904 to 1981, who was the head of the Western Electric Hawthorne plant’s Employee Relations Research Department (Whitehead & Mitchell, 1938; Mayo, 1945; Landsberger, 1958; Dickson & Roethlisberger, 1966; Gillespie, 1991; Olson, Verley, Santos, & Salas, 2004). [This psychological study was most probably an important contributor to the inclusion of the “Psychology” element in Deming’s categorization of the components of his

“System of Profound Knowledge.”]

Contemporary Influences on the thinking of Shewhart. The intellectual influences upon Shewhart evolved out of the ongoing dialog about the meaning of the scientific method. This dialog began in the prior century and was greatly accelerated and stimulated by Albert Einstein’s great revelation of the special and general theories of relativity in 1905. Einstein derived his theories through a process he called ‘thinking experiments’ which were a precursor for future scientific experimentation and useful when the ability to perform physical experiments to theoretically demonstrate is not possible (e.g., for Einstein this could not have occurred without the Manhattan Project to develop a weapon that harnessed atomic energy). This emphasis on devising improved approaches for scientific discovery was coupled with use of statistical methods applied to the task of repetitive manufacturing, the emerging emphasis on process operations in production, and a pragmatic philosophy that emphasized learning as the process of continual experimentation.

Two individuals were prime movers in influencing Shewhart’s intellectual inquiry. It is pertinent to describe their influence as a basis to understand the motivation for this study (a more detailed discussion of their important intellectual contributions will be included in the literature summary in the second chapter). These individuals are physicist Percy W. Bridgeman and George S. Radford, a quality professional (his contribution has been previously described). To understand the Shewhart theory of control requires a foundation in their writings as well as a deeper understanding of Deming, the editor and biographer of Shewhart.

By pursuing a scientific approach in his research into the possibilities for statistical applications in the control of production quality, Shewhart applied the thinking of physicist Percy W. Bridgeman. Although Shewhart had conceived of his chart earlier, it is interesting to note the close alignment in the contemporaneous thinking of these two physicists. This is a fact which was acknowledge by Shewhart when he chose as the leading citation in the preface to his 1931 book the following quotation from Bridgeman's 1927 book, *The Logic of Modern Physics*:

A situation like this merely means that those details which determine the future in terms of the past may be so deep in the structure that at present we have no immediate experimental knowledge of them and we may for the present be compelled to give a treatment from a statistical point of view based on considerations of probability (Bridgeman, 1927, pp. 116-117).

The pertinence of Bridgeman's logic to Shewhart's approach to quality analysis comes from the way that Bridgeman identified how Einstein's Theory of Relativity modified the mental model of the scientific approach and provided an inspiration for Shewhart to improve upon his control chart methodology to create a statistically-based mental model where "no aspect of psychology or epistemology is without pertinence" (Bridgeman, 1927, p. xi) and also where "any statements about numerical relations between measured quantities must always be subject to the qualification that the relation is valid only within limits" (Bridgeman, 1927, p. 33). In this way scientific pragmatism and statistical thinking became two cornerstones of Shewhart's economic approach to quality control.

The importance of sound scientific theory as the background to Shewhart's work cannot be overemphasized. According to the retrospective review by Mianti (2005):

> Theory served as the handmaiden to applied science in the development of SQC. Knowledge was not pursued for its own sake. The goals of the research program remained highly pragmatic and specific. Theory had direct and timely impact on practice. It took only four years to perfect the basic concepts underlying SQC. In this context, theory had four purposes: First, to ensure that innovative practices and procedures conformed to underlying laws of mathematics. Second, to clarify the significance of the statistical information that was used to draw inferences about business activity. Third, to provide a common basis of analysis that was comprehensible in evaluating quality

> assurance information throughout the firm. Fourth, to facilitate the broadening of learning through analogous reasoning and logicomathematical (*sic*) analysis (p. 70).

Therefore, it is sensible to believe that Shewhart's innovation in applying statistical thinking to pragmatic problems expressed ideas that were at the leading edge contemporary scientific thought leaders within the Bell Labs unit research team and the operational staff working at the Hawthorne Plant. But it was up to Shewhart to doggedly pursue his theory for over five years and to produce a series of papers in the *Bell Systems Technical Journal* to define the method.

Shewhart and development of the practice of statistical quality control. So, exactly how did scientific, statistical, psychological and philosophical thinking of his contemporaries influence Shewhart? Shewhart focused his pragmatic research into the statistical methods that could help to increase knowledge in the process of scientific inquiry and he had a firm belief that the nature of scientific inquiry could be improved by making rational decisions that satisfied a requirement for objectivity in determining the quality of a manufactured product. The cornerstones of his way of determining the quality content of work consisted of three elements which operate as a system for inquiry into the scientific nature of production process performance:

(1) A method for the analysis of process data to determine causal systems of variation using Statistical Quality Control (SQC) charts;

(2) A process for scientific inquiry (now called the Shewhart Cycle or Deming Wheel); and

(3) The theory of control which describes maturity levels for the improvement in process performance.

These three elements will be described in the following paragraphs provide a more detailed prelude to setting the specific objectives for this research with a description of Shewhart's causal system and its relationship to his design of the statistical quality control chart.

To understand how analytical methods can be employed for supporting executive decisions, it is essential to establish an improved perspective on the contribution of Shewhart in this intellectual milestone of his evolutionary progress in development of an applied theory of control. Shewhart's development of statistical quality control (SQC) charts was derived from his awareness of the contemporary dialogs regarding quality as perceived from the combined scientific, statistical, philosophical and psychological perspectives. Shewhart used a process perspective to learn about what happened in the past history of a process and applied statistical methods to analyze observations of the measured performance results as his means to achieve learning about patterns in the data which would indicate instability in process performance.

According to Shewhart two types of statistical variation in critical performance indicators demonstrate that process instability exist in a process and he referred to them as assignable and unassignable cause variation. Assignable cause variation occurs as a process changes over time and the reasons for the observed change may be found and assignable to a specific causal condition. Such uncontrolled variation is seen in patters of variation that are imposed over the random process variation and it will also produce performance that exceeds the standard operating limits. Deming called this type of variation 'special cause' variation because it is easily identifiable on a control chart and the variation may be related to specific process actions that occurred during the time series of working activities (Deming, 1994, p. 174).

"Shewhart noted that 'assignable causes of error,' were systematic and were susceptible to correction through management planning and action" (Miranti, 2005, p. 60) by making changes in the operating characteristics of the product or process by which it is produced. Thus, assignable causes of variation are capable of control and possess the inherent characteristic that they are reducible. So it is possible to 'assign' or determine the source of variation to a particular cause, action or change to standard work that may be analyzed and corrected to change process performance and thereby reduce waste or inefficiency in routine work and improve the economic conditions under which the process operates. Such special cause variation may be detectable within production process by the use of statistical analyses and is evident on Shewhart's control chart as a deviation outside the limits that may be imposed on expectations of performance when the process is operating within stable conditions which Shewhart (1931) defined the distance of an observation, measured as a function of the number of standard deviations that the observation falls away from the process mean established by its historical performance (pp. 14-24). When the cause of this extreme process performance can be traced to an identifiable condition of production, then it may be called a 'special cause' of variation which process workers can resolve as a means to improve performance. Shewhart (1931) proposed the postulate: "Assignable causes of variation may be found and eliminated" (p. 14). For Shewhart the mathematical justification for applying this rule is not as significant as its practical merit based on his philosophical perspective: "the fact that the criterion which we happen to use has a fine ancestry of highbrow statistical theorems does not justify its use. Such justification must come from empirical evidence that it works" (Shewhart, 1931, p. 18).

However, Deming was also pragmatic when he noted that "some Special Causes [of variation] can be removed only by management" (Deming, 1986, p. 320). This second type of variation Shewhart had referred to as unassignable cause variation. This unassigned variation is characterized as a chance cause produced by random variation in the process performance from its standard operating limits and it appears to be stable within limits, exhibiting a consistent pattern of variation over time. This represents controlled variation that is embedded within the process performance and operating within statistical limits of performance and is thus predictable within these limits. This type of variation indicates the way a process has been designed to perform. No repeating patterns or special causes are observed. Deming called this ‘common cause’ variation as it occurs ‘within limits’ and displays no special pattern on a control chart beyond randomness and therefore cannot be related to any specific process actions in the time series of work performed as it is only evident as a lack of variation on a control chart. However, common cause variation is ‘unassignable’ in the sense that it is generated by the system of processes that has been designed and built into the process of daily management. Since common cause variation is the result of random errors in the process performance, there is no economical means by which it can be controllable. Thus, the control chart permitted engineers to reduce the level of poor quality to the degree of the randomness that was inherent in design of the process for manufacturing and in the characteristics of the materials used for production.

Thus, common cause variation represents the intrinsic ‘best case’ of the process as designed and developed to its current state of maturity. Common cause variation is generated by the decisions of management about business policy, application of finances for resource acquisition, as well as the way organizational structure, core competence development, and policies for engagement of employees are managed. Deming also uses the term to relate to the application of the theory of knowledge to develop a probabilistic knowledge future performance.

Applying the Japanese principle that quality must be assured ‘at the source’ of activity, then responsibility for improving ‘assignable variation’ is levied upon the workers while the responsibility for addressing ‘unassignable variation’ must be assigned to the executive or management functions as they are created by a system in which the waste has been generated by executive decisions and actions that in turn generate waste and inefficiency as ‘unassignable variation’ in the workplace. Shewhart created the statistical control chart as a means to distinguish between the variations induced during work process performance as influenced by these two sources of process transformation from a stable, and therefore economic, condition of process operation.

The development of the SQC chart created tractability of performance data that "provided new insights to top management about manufacturing activities and their effect on telephone network performance that were useful in strategic planning and monitoring" (Miranti, 2005, p. 68). One early applied statistician, Purdue Professor Irving W. Burr (1953), who lived from 1908 to 1989, declared that the control chart was "the voice of the process speaking" (p. 17).

The Japanese development of quality practices. As a nation endowed with scarce natural resources, Japan developed an early fascination with application of the principles of scientific management as a way to gain competitive commercial advantage and compensate for this natural disadvantage. Japan ended its prior policy of isolation which had been established during the military feudal period under rule of the Tokugawa Shogunate (1603-1868). In 1867 the Emperor made a formal declaration of his supreme power and Japan began to confront its need to modernize society throughout the following decades, a period called the Meiji Restoration (1868-1912). This period of the Meiji Restoration roughly parallels the industrial revolution in the West and during this period Japan transitioned into a modern nation (Nonaka, 1995, pp. 517-552). One of the causes of this transformation of the Japanese governing power was the confrontation that occurred when in the period 1852-1854 when Commodore Matthew C. Perry sailed into Edo (Tokyo Bay) in modern warships whose iron cannon were far superior technology to the wooden coastal guns of Japan. Commodore Perry coerced the Japanese under threat of force into signing a treaty, the Convention of Kanagawa, which opened Japan to trade with the United States. Following this humiliation, the Emperor assumed all powers of the Shogun and took control of foreign trade agreements and modernization of Japan (Walworth, 1966). It was this humiliation that created a stimulus to transform Japan into a technological power and created its thirst for consuming knowledge about the industrial revolution and the techniques and methods of scientific management which enabled efficient manufacturing with minimal waste.

To understand the chronology of the development of Japanese TQM and the role that Deming had in influencing its development, it is necessary to view the sequence of events that occurred across five distinct periods from 1931 to 1961 (Kondo, 1988, p. 35F.2):

(1) Pre-War Methodology Development within Japan

(2) American Wartime Methodology Developments (Including Japanese Observations)

(3) Post-War Reconstruction Efforts within Japan

(4) Growth of Infrastructure to Create Unique Japanese Capability and Competence

(5) The Teaching Visits of Deming to Japan

(1) Pre-War Methodology Development Within Japan

The impact of western thinking on development of a Japanese style of management is evident in observing early translations of influential books and initial stimulation for development of a Japanese scientific approach to work came primarily from study of the work of Taylor (1911) and applications of the early work by Shewhart (1931) during pre-World War II years.

Taylor's notable book, *The Principles of Scientific Management,* was quickly published in Japan so that it was almost simultaneously translated into Japanese stating its title as *The Secret of Lost Motion* and selling a reported 1.5 million copies (Cole, 1971; Freeman, 1996; Greenwood & Ross, 1983). One of the leading proponents of scientific management in Japan during the pre-war period was Kiribuchi Kanzō who in 1935 described a scientific management control system (*kanri,* 管理) as "a technical intermediary between engineering and the economy, and as a social intermediary between capital and the masses" (Tsutsui, 1998, p. 28). Kanzō had published a book in 1934 that introduced the idea of applying statistical analysis in manufacturing process as a means to assure conformity to the standards of production in 1934. In some isolated instances experiments with this idea had begun; however, Kanzō was the first to present this idea for public consideration (Tsutsui, 1998, p. 191).

Yoshio Kondo (1988), who lived from 1924 to 2011, summarized the pre-war Japanese industry situation:

> Prior to World War II, Japanese research on and application of modern quality control (QC) were limited. Japanese product quality was poor relative to international standards. These poor products were only sold at ridiculously low prices, but it was difficult to secure repeat sales. Among the exceptions were some Japanese companies that made high-technology products primarily for military use, but without successful application of mass production technology (p. 35F.1).

In his retrospective studies of the sociological influence of participatory management in Japanese companies, Professor Robert E. Cole (1989) of the University of California at Berkeley had observed that:

> From a cultural point of view, it is important to note that while Japanese managers adapted foreign ideas to their own needs as they saw them, they felt little need to naturalize them for the sake of avoiding 'foreign pollution.' As we have seen, American management was held in high esteem, and any adaptation could thus proceed on relatively pragmatic terms. The Japanese have, of course, a long history of borrowing ideas from foreigners, most notably from the Chinese in the pre-modern era and from the West over the past one hundred years as they sought to 'catch up' with the advanced industrial nations. Based on these historical experiences, they have institutionalized a highly eclectic approach to learning (pp. 113-114).

Japan had developed a number of national institutions with governmental subsidies to increase its eclectic technology transfer from the West. A Labor Management Cooperation Society was established in 1919 with a specialized subsidiary called the Industrial Efficiency Institute to promote scientific management and later the interest in scientific management came through the Japanese Industrial Association, established in 1931, and "was designed to disseminate scientific management" as a strategic approach "to overcome world-wide economic depression" (Cole, 1989, pp. 113-114).

There is even evidence that Japan had applied Shewhart's control charts for industrial applications in quality as early as 1933 when they were introduced to Japan by Yasushi Ishida at Toshiba and called *makimona* charts (scrolls of control charts). Ishida learned about this methodology after writing a letter to Egon Pearson in England. Pearson invited Shewhart to visit England and lecture the Royal Statistical Society about his discoveries on the methodology of statistical quality control in 1932. This lecture had stimulated Pearson to incorporate SQC into the first European standard on this topic which he prepared as a book in 1935: *The Application of Statistical Methods to Industrial Standardization and Quality Control* (British Standard 600:1935) (Nonaka, 1995, pp. 519-520; Pearson, 1935). By 1933 Ishida had developed his own methodology for using these charts to evaluate production of light bulbs. However, application of these charts was highly compartmentalized in Toshiba, almost as if it were an industrial secret. Eizaburo Nishibori, an early leader in the Japanese quality community and a highly-placed leader in Toshiba, had not been aware of the use of these charts nor had he seen these charts even as late as 1947 (Nonaka, 1995, p. 520; Pearson, 1935; Radford, 1922; Shewhart, 1931; Shewhart; 1939). Interest in these topics increased during the wartime years as both Japanese and American industries needed to mass produce the instruments of war at higher levels of quality.

(2) American Wartime Methodology Developments (Including Japanese Observations)

Nonaka's (1995) essay on Japanese quality indicated two additional instances of SQC technology transfer that occurred during the early war years as Toshio Kitagawa of Kyushu University and Ishida translated Egon S. Pearson's book into Japanese in 1942 (p. 518). In addition, they also collaborated to translate the 1942 report: "Report of the War Preparedness Committee of the Institute of Mathematical Statistics" (Eisenhart, Craig, Olds, Simon, & Wareham, 1940, pp. 479-480) which described how to apply statistical methods and thinking to support a wide variety of war-related preparations. However, there was a very weak implementation of these methods during the war period as these statistics did not make sense to the Japanese workers as "factory workers were simply doing their best to increase output, and the advice of the statisticians seemed too remote, couched as it was in difficult terminology. In fact, one of the major bottlenecks in the prewar and wartime application of SQC was the difficulty of the language used to describe the concepts, preventing the spread of knowledge to the shop floor" (Nonaka, 1995, p. 522).

Two parallel efforts at modernization of American industry occurred during the wartime period. One effort industry improvement effort actually preceded war and it continued through the entire period: the Training Within Industry (TWI) program was created by the United States Department of War within its War Manpower Commission and was conducted from 1940 to 1945. TWI concentrated on development of human relations-based improvements and its core program consisted of four basic training courses (each one was taught as a 10-hour module) which were developed for TWI by experts on loan from private industry and focused more on human relations and job design. By the end of the war, over 1.6 million American workers in over 16,500 plants had been trained in this program which was supplemented by skills in job safety, problem solving, facilitation skills, and supervisor training (Warren, 2010). Especially notable in this training was the four-step instructional process that TWI developed from a learning model proposed by Charles R. Allen (1919): Prepare the Worker; Present the Operation; Try Out the Performance; and Follow Up which is strangely similar to the PDCA Cycle. This learning model for improvement of industrial performance was built into all of the training materials and served as a core component in all of the TWI education and was later another influence on the development of continual improvement models in Japan.

In 1941 Army Captain Leslie E. Simon (1941), who lived from 1900 to 1983, wrote one of the first practical books on the application of statistics to engineering problems [he retired as a Major General] (Butterbauth, 1946; Dodge, Ashcroft, Simon, Wareham, & Gaillard, 1942; Grant, 1946; Michelon, 1942; Peach, 1945). Simon was attached to the War Production Board (WPB) which had been set up in early 1942 by executive order to direct war production and material procurement. It was granted extensive powers over the national economy to convert a peacetime economy into an optimized wartime production capacity. One of the WPB activities was educating US industry about statistics which was conducted by the Office of Production Research and Development (OPRD) which developed and administered an SQC training program. This program was started at Stanford University by Eugene L. Grant (1897-1996) and it was later moved to the Carnegie Technical Institute for administration under Holbrook Working (1895-1985). Instructors taught the 10 day SQC Course across the various production factories in American industry and eventually trained some 7,553 engineers through the WPB Engineering, Science and Management War Training program. Instructors who taught this program included some of the leading statisticians in America at that time (see Table 9 for details about these instructors (Working & Olds, 1945)).

Name	Institution	Number of Courses
Holbrook Working	Stanford University	26
Eugene L. Grant	Stanford University	6
Edwin G. Olds	Carnegie Institute of Technology	19
Paul Peach	Carnegie Institute of Technology	14

Cecil C. Craig	University of Michigan	8
Edward Schrock	Aberdeen Proving Ground	5
Martin A. Brumbaugh	University of Buffalo	4
Irving W. Burr	Purdue University	4
Ralph E. Wareham	General Electric	4

TABLE 9: Instructors in the American SQC Course for Industry

Did the Japanese develop a similar working group to disseminate and promote the methods of statistical quality control into industry during the war? Evidence does not point to this.

> In 1943 a "public-private 'research group' of engineers and statisticians was established under the auspices of the Technology Agency to study mathematical approaches to mass production. Nevertheless, such wartime initiatives remained more theoretical than practical in outlook. Although the traditional Taylorite [*sic*] techniques for assuring quality (particularly inspections) were widely used, modern statistical QC was not systematically applied in any Japanese workshops before 1945 (Tsutsui, 1998, pp. 191-192).

(3) Post-War Reconstruction Efforts within Japan

The post-war incentive for increased emphasis on quality was a harsh dose of reality for Japanese managers. Japan welcomed an extensive educational program in how to apply the 'modern methods' but became disappointed and disillusioned that these were not 'magical' and that in fact most of the 'technology' had been learned previously. The 'new' ingredient was the blending of the human resources movement with the SQC learning into a new type of management quality program – the beginnings of Japanese TQM whose development was pursued by three different organizations that grew up in this post-war era: the Japanese Statistical Association (JSA), Japanese Management Association (JMA) and the Union of Japanese Scientists and Engineers (JUSE). Tracing the development of the training programs that influenced the blossoming in the 1950s is an instructive way for understanding the context of the transition from isolated knowledge in to a system of profound knowledge.

In a comprehensive scholarly text that focused on the history of the development of Japanese industrial management during the twentieth century, Professor William M. Tsutsui of the University of California at Berkeley cited an observation by the influential Japanese industrial engineer Shigeo Shingo (1909-1990) from 1951: “Shingo explained in 1951 [that] there were two fundamental elements to manufacturing: the methods of work (as determined through scientific management) and the will to work (as addressed by HR)” (Tsutsui, 1998, p. 158). In Japan the blending of human relations thinking with scientific management’s technical and statistical methods was occurring as a natural outgrowth of management and academia curiosity. This contrasted to the American path where these approaches were developing as juxtapositioned and often opposing ideologies (Tsutsui, 1998, p. 158).

The early emphasis on human relations could be seen in the Western influence on the curricula developed for management re-education following the war. Yoshio Kondo and Izumi Nonaka report that the first quality course delivered in post-war Japan was taught at the end of 1945 by Wilbur G. Magill (1897-1972), a Western Electric engineer who was a supervisor in the Industrial Division of the Civil Communications Section (CCS) of the General Headquarters (GHQ) within the Supreme Command of the Allied Powers (SCAP). He was replaced in this position by Homer M. Sarasohn (1916-2001) in 1946. A major problem in the post-war period was the lack of quality and reliability in the vacuum tubes used in the civilian telecommunications system and engineers from Western Electric, Bell Labs, and Raytheon Manufacturing were invited to Japan to teach the Japanese telecommunications industry (including Nippon Telephone & Telegraph) how to correct this problem (Kondo, 1988, p. 35F.2; Nonaka, 1995, p. 522). Nonaka (1995) observed that “half of the CCS staff were actually AT&T employees. Most of these came to Japan for two to four years and then returned to their posts at AT&T and its subsidiaries (the regional Bell Telephone Companies, Western Electric Company, or Bell Telephone Laboratories)” (p. 522). CCS Staff members who instructed in quality, statistics and industrial management and terms in Japan were: Magill of Western Electric (served 1945-1946), Sarasohn of Raytheon Manufacturing Company (served 1946-1950), and Charles W. Protzman (1883-1971) of Western Electric (served 1948-1950) (Nonaka, 1995, p. 522).

Sarasohn and Protzman taught a course titled “Fundamentals of Industrial Management” to senior Japanese business leaders because they had recognized Japanese management lacked the understanding of “modern” management methods. This class was developed as a university level program for Japanese managers to apply a very broad concept of industrial management and it used only three books as references. The course had limited effect as it was only delivered twice (once in Tokyo in 1949 and once in Osaka in 1950). While the content of their program was a broad overview of industrial management based on the ‘latest thinking’ of its time, it is evident that they introduced many new ideas to their students. Some of the germane topics in their curriculum included (Alford, 1947; Kimball, 1939; Holden, Fish, & Smith, 1947; Sarasohn & Plotzman, 1998, p. iv):

- Business policy describes at a management-level how people in an organization have decided to work together to accomplish purpose for an organization’s existence

- Criteria to determine the adequacy of business policy–it is important for workers to be given flexibility to operate within the established policies for business practices

- Leadership and policy enforcement–wise leadership is essential for good policy

- Examples of operations policy–selection of the best way of working

- Standard policy–adherence to the one best way of doing work
- Responsibility for policy adherence–need for harmony (Sarasohn & Plotzman, 1998, p. iii)

Sarasohn wanted to encourage Japanese managers to use participative management, which he interpreted as a foundation for the new social democratic system that was being established in Japan and executed through the reconstruction program. The perspective of Sarasohn was to identify the policy for an organization and to get everyone involved in an on-going process of continual improvement in the execution of that policy. Thus, each person would be committed to defined goals that aligned with the spirit of the enterprise and would gain a personal sense of ownership of their work within the organization and feedback with the idea of doing their job right the first time and communication to keep the sense of ownership and commitment alive and well. These principles were foundational for policy management laid a foundation for management by results when Drucker came to Japan later (Fisher & Nair, 2009; Fisher, 2009).

Sarasohn and Protzman had also defined a five-step problem-solving approach which they introduced as scientific management and was largely based on the work of Taylor (Watson & DeYong, 2010, pp. 66-84):

(1) Define the problem precisely.

(2) Get the facts – all the facts.

(3) Analyze those facts to decide upon a proper course of action.

(4) Put the plan of action into effect with the expected results identified.

(5) Monitor the plan in progress; make necessary timely adjustments.

In positioning the rational for delivering these two courses Protzman (1950) commented, as follows:

> It was evident that no general progress could be made until top management were brought to realize the situation, were convinced of the need for action and were prepared to provide sound leadership and guidance in the promulgation of programs for improvement. This must be our first objective (p. 4).

While the CCS program was innovative, it has not gathered as much notoriety as that accorded to Deming's visit (Hopper, 1985; Hopper & Hopper, 2007). This lack of appreciation for long-term contributions for the recovery of Japan is also true of other educational programs that were established in this same period.

(4) Growth of Infrastructure to Create Unique Japanese Capability and Competence

Just after the war, three professional organizations in Japan began to develop QC training programs that offered education in statistics in the context of human resource management of quality: Japanese Management Association (JMA); Japanese Standards Association (JSA), and the Union of Japanese Scientists and Engineers (JUSE). These three groups shared the common agenda of stimulating the economic recovery of Japan and they shared a similar interest in scientific methodology and, to a somewhat lesser degree, human resource management (Nonaka, 1995, p. 529).

JMA had been established in 1942 and it launched its first QC research program in 1947 (which later became an initiative for "Zero Defects" 1966. The instructors for the JMA program were Nishibori and Shingo. In 1945 Shigeo Shingo started to work at JMA in Tokyo, becoming a consultant focused on the improvement of factory management. In 1946 Shingo reported at a JMA Technical Conference that processes and operations are inseparable and he began his investigation into productivity problems and plant lay out. Following 1947, in fact, Shingo had been teaching this same course in many areas of Japan emphasizing the fundamental techniques of analysis and improvement of the operational activities in factories in what became known as the P-Course, or Production Course. Shingo did not begin studying SQC until 1951 and it was not until 1954 that he was hired as an industrial engineering consultant to Toyota. However, from 1956 he taught this course at Toyota 79 times over a 20 year period and over 3,000 production technicians were instructed in a combined class room and shop floor teaching style that Shingo referred to as "learning by doing" or implementing classroom lessons on the shop floor instead of merely discussing theory (JMA Group, 2010; Smalley, 2006).

In addition to the lectures on industrial management by CCS, post-war training was also offered through the Training Within Industry (TWI) program, a program exported from its American roots as a wartime factory training program and which was jointly sponsored for instruction in Japan by the Labor and Economic Section of GHQ and the Japanese Ministry of Labor in 1951 for a six month period with a second round of training engaged Toyota among other companies. This training was led by Raymond B. Richardson (1917-2009) (Training Within Industry, Inc., 1951, p. 4; Sarasohn & Protzman, 1949; Tsutsui, 1998, pp. 161-163; Reynolds, 1948; Herdan, 1948; Moroney, 1951; Freeman, 1951; Freeman, 1952; Burr, 1953; Crow, Davis, & Maxfield, 1955; Small, 1956). In addition to the courses offered to American factories, TWI developed a twenty-two session Management Training Course that borrowed heavily from the CCS program with the remaining material taken from the wartime training programs. So, through the TWI course on management, the legacy of Sarasohn and Protzman has been conveyed indirectly into the evolving modern culture of Japan.

Courses in statistical methods for quality control offered after the war through JSA were taught by Yasushi Ishida of Toyota, "following a quiet pursuit of his pioneering efforts" (Nonaka, 1995, p. 522).

The third provider of statistically-based training after the war period was JUSE. "JUSE was started on May 1, 1946, but predecessor organizations can be traced back to 1918" (Nonaka, 1995, p. 522). In the period after its founding, JUSE recognized a need to develop a training program on SQC that could be offered to develop a professional core of managers in Japanese factories. JUSE "offered its SQC seminar (now known as "the QC Basic Course") over the year long period from September 1949 to August 1950. The course was subsequently offered for the second time over a six month period [editor note: prior to Deming's lectures]" (Nonaka, 1995, p. 522). JUSE did not have a broad body of knowledge to draw from in developing this course. "The SQC seminar was based on material written by E. S. Pearson, Shewhart, H.F. Dodge and H. G. Romig, in addition to translations of Z1-1 and Z1-2 (American War Standards). The first such JUSE seminars took place in the form of lectures based on translated foreign texts on SQC" (Nonaka, 1995, p. 521).

JUSE was not pleased with the results of the initial offering of this course as can be seen from the comments made in an interview with the second President of the American Society for Quality Control (ASQC), Ralph Wareham: "prior to Dr. Deming's visit to Japan, JUSE requested (or more precisely the request came from Ichiro Ishikawa (Kaoru Ishikawa was the oldest of his eight sons) through the CCCS Division of General Headquarters of the Supreme Commander of the Allied Powers (where Sarasohn and Protzman worked) the full set of materials for the "Eight Day Statistical Quality Control Course" to be translated into Japanese. This occurred in 1948 while Wareham was President. Based on the translation of this material Ishikawa developed the first JUSE Basic Quality Control course in 1949. However, the lack of satisfaction with being able to instruct this material without having had the practical experience in applying it lead to the invitation (also encouraged by Ichiro Ishikawa) of Dr. Deming to come to Japan to teach the course" (Watson, 2010, pp. 9-10).

In describing the history of JUSE Kondo commented that: "among JUSE's early activities was the formation of the QC Research Group in 1949, which included Professors Asaka, Ishikawa, Kogure, Mizuno, Moriguchi, etc., many of whom became Deming medalists and members of the International Academy for Quality (IAQ). With these people on the teaching staff, JUSE Opened a 6-month basic QC course in 1949" (Kondo, 1988, p. 35F.2).

(5) The Teaching Visits of Deming to Japan

While some of the circumstances regarding Deming's visit to Japan are not clear (Tsutsui, 1998, pp. 197-201), it is well-documented that "when Mr. Kenichi Koyanagi, managing director of JUSE [Koyanagi served in this position while Ichiro Ishikawa was Chairman of JUSE], learned that Deming would be visiting Japan in May 1950 in his capacity as advisor on sampling to GHQ, he asked Deming to deliver lectures during his stay… Dr. Shigeru Mizuno, a JUSE instructor and Deming lecture participant, recalls that: "The JUSE [basic course] instructors were, up until that time, merely self-taught concerning [the fundamental ideas of] quality control but, through Dr. Deming's lectures, they were able to approach for the first time the true essence of quality control. The lectures had a great historical significance for the history of quality control in Japan" (Nonaka, 1995, p. 532).

Deming delivered two 8-day QC courses for JUSE's in the summer of 1950, modeled after the wartime SQC course delivered in the US. The content of the initial Deming 8-day lecture was mostly statistics (7 of 8 days) and it was not really new as many of these people had and studied the pre-war Bell Laboratories material that had been translated and were familiar with these methods. Tsutsui (1998) reports that many of the attendees were disappointed in the lack of revelation of new learning: "thinly veiled expressions of disappointment and disillusionment were common in JUSE publications. Expecting to be dazzled with new statistical advances from the United States, many Japanese observers were discouraged to find that Deming had no new tricks to pull from his statistical hat" (pp. 198-199). However, he also provided a one day seminar for top management which was based on his own design which was met with greater response by its largely executive audience (Nonaka, 1995, p. 532).

What was the information that Deming conveyed in this 8-day course? According to Colombia Professor Peter J. Kolesar (1994), Deming covered just six topics in extended lectures:

- Controlled and uncontrolled variability,
- Some elementary ideas regarding the control chart,
- Plotting a control chart. Control chart method for judging whether control exists,
- Some experiments with a controllable process,
- Control chart method of controlling quality during production, and
- Acceptance Sampling (p. 12).

The JUSE QC Research Committee continued to operate and refine its teaching of the Basic QC course and this “course was held 147 times through April 1983 and was attended by 18,127 engineers, who went on to provide the nucleus of QC activities in their respective companies” (Kondo, 1988, p. 35F.2).

On reflection, one should ask, what was the real influence that Deming’s visit had on Japan? In light of the exaggerated claims that are made by Deming and others, this is a very serious question (Fisher, 2009, pp. 285-287; Tsusui, 1998, p. 197; Cole, 1987, 49-51). Professor Cole (1987) concluded that: “much of what is now called the Deming method… are not ideas that Deming taught the Japanese but principles that he learned while watching the Japanese develop” (p. 50). He continued in his comments: “The Japanese, by virtue of their late-developer status, have continually struggled to catch up to the West. Thus, they have instinctively understood these principles and have never hesitated to learn from foreigners; they have actively sought such knowledge and adapted it to their environment” (Cole, 1987, p. 51).

In 1954 Juran was also invited to lecture Japanese managers and executives by JUSE. In his two lectures, Juran addressed executives and senior managers in two days and delivered a 10 day lecture for middle managers. In the words of Kaoru Ishikawa, Juran was invited to speak as a means “to help solve the problem (of an over-emphasis on statistical methods.” In other words the balance between the SQC component of quality and the human relations component of quality had not been gained as of this time (Kolesar, 2008, pp. 7-16). In the preface to the Japanese edition of Juran’s hand book on quality (incidentally, the title of the handbook had been translated in the Japanese as *Total Quality Control*), Juran (1954) commented: “… there has been some over-emphasis of the importance of the statistical tools, as though they alone are sufficient to solve the quality problem. Such over-emphasis is a mistake. The statistical tools are sometimes necessary, and often useful. But they are never sufficient” (pp. 12-17). Thus, Juran turned the thinking from a myopic focus on scientific management to a broader focus on managing for quality as the objective of the organization. Juran called scientific management an emphasis on the “little q” type of quality action which concentrated on operational matters in the daily management system. He also defined what he called “Big Q” Quality which delivered breakthrough change. How do the two differ? Consider the analogy: scientific management (exercise of “little q” quality) is to processes what scientific leadership (exercise of “Big Q Quality) is to organizations. Using this analogy, scientific management focuses on work discipline using a theory of control for the managing work process outcomes with ‘little e’ efficiency measures of quality, cost, and time. However, scientific leadership delivers strategic improvement projects to achieve breakthrough change to significantly improve drivers of ‘Big E’ system-level efficiency in the organization’s routine way of working by working smarter to achieve the organization’s strategic intent (Juran, 1964).

Deming and Juran were not the only people to influence Japanese quality. Philip B. Crosby was the head of quality at the Martin Company where he created the Zero Defects program which was initially used on the U. S. Army Pershing missile program (Office of the Assistant Secretary of Defense (Manpower Installations and Logistics), 1965, p. 3). Cole (1989) reported how one Japanese company merged their internally developed company quality, as follows:

> …programs with the zero-defect (ZD) program in vogue in Japan at that time. ZD was also a U. S.–originated program, begun as a motivation campaign for workers aiming at zero production defects by quality control personnel at the Martin Company in connection with its contract for the U. S. Army's Pershing missile program in the early 1960s. The program was modified by the Japanese to stress small-group processes and in turn has subsequently merged with the quality-circle concept in the eyes of most Japanese managers. We see in microcosm here the process by which Japanese students of American social sciences and organizations incorporated their new ideas and modified them in course of applying them to Japanese work organizations. We also see how they merged with the different streams of development arising from the technical quality-control discipline, as well as with traditional approaches to group activity in industry (pp. 96-97).

From this example, and others, Cole (1989) concluded that "we can obtain a sense of the capacity of the Japanese to borrow and adapt Western organizational technology to their own needs" (p. 96).

Notably, however, even Juran had a feeling that the Japanese built the momentum for change largely on their internal initiative. In an interview Juran once reflected that: "Had Deming and I stayed at home the Japanese would have achieved world quality leadership all the same" (*Financial Times*, 1993). Certainly the intensity of the Japanese effort to master the field of quality was organized in a much more thorough manner than in any other nation during this epoch.

Subsequently, in the 1980s JUSE and JSA sponsored a series of research projects to expand the structure of quality theory and practice and to broaden the understanding of the human components of interaction among organizations. The series of research committees sponsored in the late 1980s is presented in Table 10 (Watson, 2010, p. 45).

Research Committee	Human Motivation	Cross-Functional Management	Hoshin Kanri	Quality Function Deployment	Problem Solving
Chairman	Yoshio Kondo	Kenji Kurogane	Yoji Akao	Yoji Akao	Katsuya Hosotani
Sponsor	JSA	JSA	JSA	JUSE, JSA	JUSE
Membership	Academia: 2 Industry: 7	Academia: 2 Industry: 8	Academia: 3 Industry: 5	Academia: 3 Industry: 9	Academia: 3 Industry: 7
Dates	1984-1988	1984-1988	1984-1988	1978-1988	1984-1985
Major Findings	New Japanese theory of human motivation	Standard way to manage cross-functional groups	Standardized approach to use of hoshin kanri for TQM	Develop voice of customer & house of quality matrices	Fourteen step process for TQC problem-solving
English Printing	3A Corporation	Productivity Press, 1992	Productivity Press, 1991	Productivity Press, 1990	Productivity Press, 1991

	Press, 1991				

TABLE 10: Japanese TQM Research Committees

The committees followed a fixed formula in their inquiries: academic investigators lead the development of theory; leading practitioners demonstrate and test the theory in their operational environment; and business leaders stimulate the change and promote the methodology through acts of persuasion. The five Japanese Research Committees identified here developed core concepts that are foundations of modern Japanese quality thinking and the information shows the dedicated focus to implement this learning strategy:

A concerted effort was made by the Japanese to blend together the statistical and human aspects of quality. This effort began in the 1930s and became even more focused following the war. In an appendix to the research report on the Hoshin Kanri Research Committee of the Japanese Standards Association, edited by Yoji Akao, a list of translated works related to management of human resources and motivation was included (summarized in Table 11 (Akao, 1991, pp. 180-183)). This clearly identifies a deliberate Japanese research strategy to develop a unique Japanese body of quality knowledge based upon the best knowledge to be gained from the West.

Author	Title	English Publication Date	Japanese Publication Date
Peter F. Drucker	The Practice of Management	1954	1954
Abraham Maslow	A Theory of Human Motivation	1943	1960
Douglas McGregor	The Human Side of Enterprise	1960	1960
Edward C. Shleh	Management by Results	1961	1963

Abraham Maslow	Toward a Psychology of Being	1962	1964
Armand V. Feigenbaum	Total Quality Control	1961	1964
Rensis Likert	New Patterns of Management	1961	1964
Peter F. Drucker	Managing for Results	1964	1967
Frederick I. Herzberg	The Motivation to Work	1959	1969

TABLE 11: American Books on Psychology and Work That Have Been Translated Into Japanese

Thus, Japanese quality management was greatly influenced by American 'humanistic psychology' in its approach to defining work and establishing methods for work process improvement. It is clear that since the early modernization of Japanese management by Konosuke Matsushita (1986), that senior leaders in Japan were intimately aware of human issues in the workplace and incorporated concern for workers in their earliest twentieth century writing on this topic. Their interest in psychology continued throughout the 20th century. This conclusion is quite evident when comparing the date of publication of these texts in English with the date that they were translated into (Akao, 1991):

Different Japanese companies sponsored these translations and upon their completion, they were studied by the leaders of the Japanese quality movement and they were included as the foundation of research conducted by university students.

The significance of this blending of scientific methods with human relations aspects of quality becomes evident when one considers the understanding that the Japanese had about the origins of waste and inefficiency within organizations. The Japanese consider waste to be any activity that adds cost or time but does not add value as judged from the customer perspective or any activity that increases risk to employees through hazardous working conditions. There are three Japanese words that describe different classifications and sources of waste and inefficiency: 'muri,' 'mura,' and ‘muda.’ Each of these words begins with the kanji character ‘mu,’ which means ‘no.’ However, these three ‘no’s’ have different meanings and a complex application. It is commonplace to hear people who have been trained in Japanese manufacturing techniques that had originated within the Toyota Production System (TPS) speaking about the need to eliminate waste using only the Japanese word ‘muda’ to define it. However, there are other sources of variation that will have consequences which prove inefficient. Shigeo Shingo (1989), who lived from 1909 to 1990, industrial engineer and designer of methods for Toyota, commented that: “so much waste remains hidden in processes and operations” (p. 80). Taiichi Ohno (1988), who lived from 1912 to 1990, Vice President of Manufacturing at Toyota and principal architect of the Toyota Production System (TPS) stated: “insufficient standardization and rationalization creates waste (*muda*), inconsistency (*mura*) and unreasonableness (*muri*) in work procedures and work hours that eventually lead to the production of defective products” (p. 41). The distinctions between these three terms show how sources of waste and inefficiency may be addressed or reduced. The conditions for these three categories of waste and efficiency (see Table 12) may be defined a little more broadly than usual as they operate in the following ways (*Kenkyusha's New Japanese-English Dictionary*, 2003, pp. 2530-2537; Watson, 2015, pp. 19-23):

Japanese Term	Translation
Muri (無理)	Waste from bad thinking; irrational waste. Muri waste arises from poor decision making (e.g., unfortunate executive strategic choice which results in overburdening the working system).
Mura (無斑)	Waste from unbalanced working or flow waste. Mura waste arises from a poor

	integration of work activities (e.g., which results in a work load that is unbalanced across the supply chain).
Muda (無駄)	Waste from poor working discipline or process waste. Muda waste arises from poorly implemented operations (e.g., waiting time, bad quality parts, etc.).

TABLE 12: Three Categories of Waste and Efficiency

Yasuhiro Monden (2012) summarized the Japanese approach to waste in the following way: "our approach has been to investigate one by one the causes of various 'unnecessaries' [*sic*] in manufacturing operations and to devise methods for their solution, often by trial and error" (p. xxiii). Each of these wastes may occur at any level of an organization! The most problematic issue is the 'assignability' required to establish causation of prior events on subsequent results. The most likely cause of both muri and mura waste are from what Deming called the 'common cause' systems of variation; however, these types of waste will generate muda waste which operators cannot eliminate as the cause is beyond their area of responsibility so that decisions related to muri and mura waste become principally decisions for management–and the responsibility of the executive function. This observation sharpens the research inquiry: how does EDM reduce waste generation by increasing quality decisions that deliver excellent results.

The elimination of waste, inefficiency and poor quality occurs in a Japanese TQM system through the continual improvement process which is represented by a decision model that was derived from the Deming Wheel interpretation of the Shewhart Cycle as developed in the 1950s by the Japanese Union of Scientists and Engineers and referred to as the Plan, Do, Check, Act or PDCA model. The development of this model is credited to Shigeru Mizuno (1910-1989) who chaired the 1949 QC Research Group that developed the JUSE basic QC course [other members included: Tetshichi Asaka (1914-2012), Kaoru Ishikawa (1915-1989, Masao Kogure (1915-2000), Masao Goto (1913-2000), Hidehiko Higashi (1915-present), Shin Miura (1910-1996), and Shigeiti Moriguchi (1916-2000)]. The PDCA model developed under Mizuno was inspired by Deming's lectures in the 1950s where Mizuno was the note-taker. The PDCA model describes a general approach to gain scientific learning and address opportunities to improve efficiency, reduce waste or perform other enhancements. In chapter one a historical development of the model was explained as it is used in the inquiry process that guides the executive function to develop profound knowledge to support critically significant decisions (Imai, 1986, p. 60; Kano, 2005; Kondo, 1988, p. 35F.2; Mizuno, 1988).

By what mechanism does the executive function generate systemic inefficiency and waste through its design and development of common cause process of management which produces 'unassignable variation' at the working level of the organization? This is a critical question which remained unaddressed by Shewhart and Deming; however, it is at the core of the EDM process as common cause variation originates in design limitations of a system and is typically imposed as a decision constraint at the time of action choices: whether it is the investment into a new venture; purchase of hardware or software; development of a business process or market; or engagement of consulting services.

(6) American Invention of Benchmarking in Response to the Japanese Challenge

The history of the development of the Xerox Corporation's program of Leadership through Quality as stimulated by the threat of competition from Japan has been well-documented along with its response in the development of what it originally called "competitive benchmarking" (Camp, 1989; Palermo & Watson, 1993; Watson, 1992; Watson, 1994). For the purpose of this history, the derivation of the mental models for benchmarking at Xerox was stimulated originally by Yotaro Kobyashi (1933-2015), CEO of the Fuji Xerox unit of Xerox Corporation, collaborating with Frank J. Pipp (1926-), Group Vice President of Manufacturing for Xerox, defined the initial approach in the late 1970s, Their initiative provided critical insight into an intellectual transfer of Japanese quality thinking which became infused into the Xerox benchmarking movement which continued growing through the mid-1990s. The development of benchmarking at Xerox is summarized in one of the early books on the subject (Watson, 1992, p. xxi). The first mental model for benchmarking was documented by Robert C. Camp in 1989 (Figure 15 (Camp, 1989, p. 6; Elmuti & Kathawala, 1994, pp. 229-243))

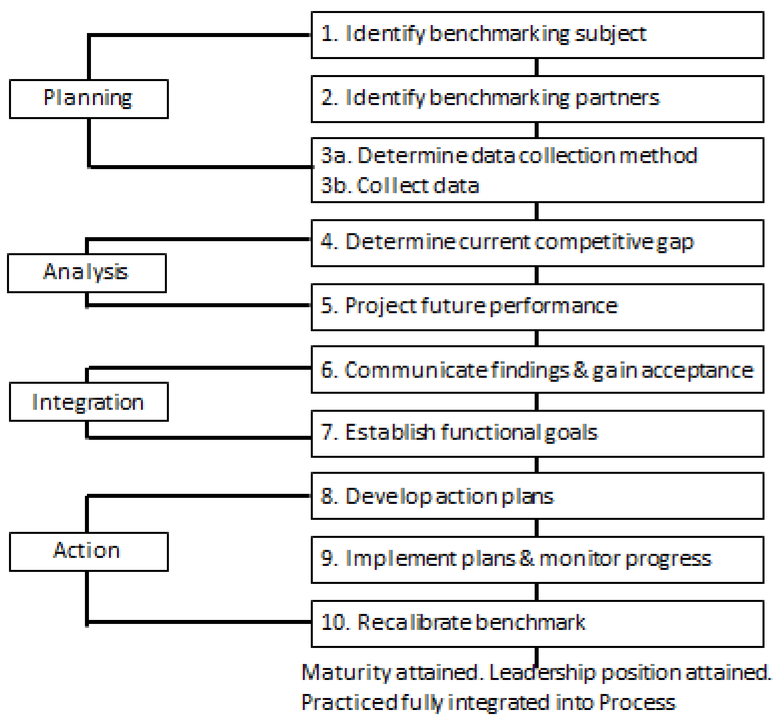

FIGURE 15: Xerox Benchmarking Model

The Xerox method allowed an organization to “triangulate” between two known sets of measured performance and to estimate performance of a third organization. By comparing the way that the processes operated at the known organizations, it was possible to estimate the way that the “unknown” process could be operating. The emphasis by Xerox was initially on the competitive organizations and seeking to learn about them. However, it became clear by 1988 that there was more to learn about process performance by benchmarking non-competitors and to use the method for continual improvement (Elmuti & Kathawala, 1994, pp. 230-231). A more simplified benchmarking model was created at Compaq Computer and published in 1992 (Figure 16 (Watson, 1992, p. 12)):

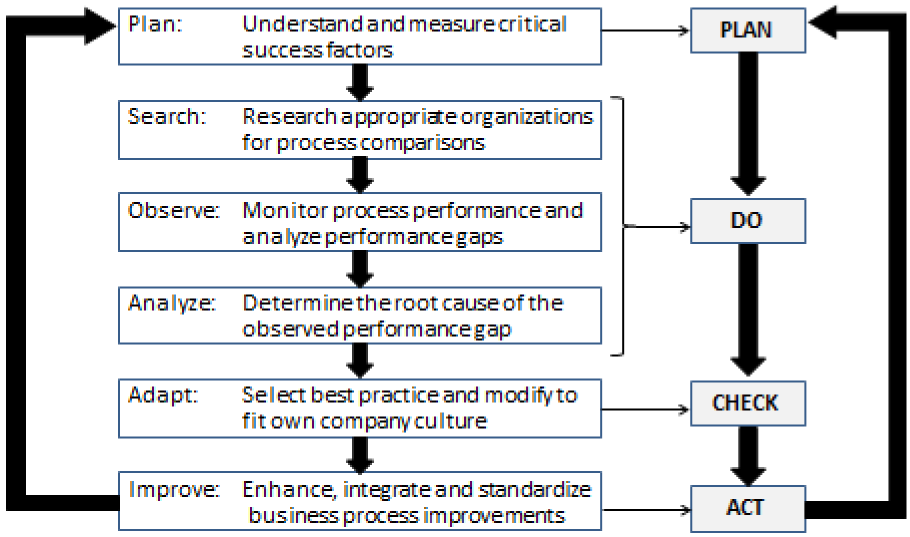

FIGURE 16: Compaq Benchmarking Model

During late 1991 to early 1992 the Compaq mental model was simplified by the staff at the American Productivity & Quality Center (APQC) as they formed the International Benchmarking Clearinghouse (IBC) as a consortium of industrial organizations who were interested in using a more rigorous approach to benchmarking for collaborative studies in generic processes. This model was combined in a classification framework of business process categories which APQC developed in collaboration with its members (American Productivity & Quality Center, 2006). The simplified APQC model was published in a 1993 book, *Management Guide to Benchmarking*, and has been the core methodology for use by the member organizations of the APQC Clearinghouse since that time (Figure 17 (Watson & Wexler, 1993)).

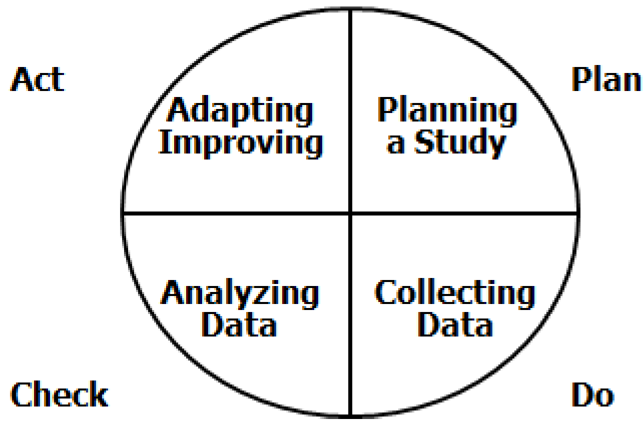

FIGURE 17: APQC Benchmarking Model

Benchmarking is a process for shared organization learning and its popularity opened the way for additional thinking about learning organizations as a mainstream business activity. Investigation of the approach to develop an organization that is sensitive to adaptive learning is discussed in the next section.

4.6 The Evolution of Thinking About Learning

Learning evolved as a subject worthy of study with the evolution of educational philosophy by John Dewey who argued that education and learning are social and interactive processes and that people must take part in their own educational and learning experiences. His book Democracy and Education (1916) established a principle that democratic principle of education should focus on involving students in the learning environment (student-centered) rather than being objects of the teachers expounding (teacher-centered). Dewey (1916) states "education consists primarily in transmission through communication. Communication is a process of sharing experience till it becomes a common possession. It modifies the disposition of both the parties who partake in it" (p. 11). The way to describe this interactive learning environment is through the development of a mental model that explains its operation simply.

Kenneth J. W. Craik wrote *The Nature of Explanation* (Craik, 1943) in 1943 and introduced the idea of a mental model by describing how the mind forms "small-scale models" that are simplified views of reality and it uses them to explain its observations of reality as well as to anticipate and to predict future performance. Mental models tend to be static and deterministic rather than dynamic and stochastic and they may be scaled from highly detailed micro-perspectives of work to the broad brush macro-perspective of the entire environment (Johnson-Laird & Wasson, 1974; Johnson-Laird, 1983; Johnson-Laird, 2004; Nersessian, 1993).

Learning has been a recurring theme in quality improvement since its first introduction by Shewhart in his early writing. The evolution of the Shewhart Cycle over a 60-year period to the point where Deming considered learning in his *New Economics* referred to his PDSA mental model as a "flow diagram for learning and improvement" which indicates the tight coupling of mental models for improvement with learning systems (Deming, 1994, p. 132).

In the 1980s and early 1990s American business introduced Japanese TQM as adapted from the lessons with their growing competitors from Japan and they linked their models for learning by interpreting them through the lens of the Japanese PDCA Cycle. For example, when Hewlett-Packard adapted TQM to fit its global culture one significant insight gained in their study and development program was the creation of a mental model for the Process of Management (POM) based on the mental model of PDCA (HP Corporate Quality, 1987). The POM model defined a non-content-specific generic process for managing as a process. It featured teamwork and a consensus-based style for managing change in organizations. This model was developed through a study of the most successful Hewlett-Packard managers who were managing key work processes within divisions of HP (see Figure 18). Also, this set of lessons learned originated from a business need to learn based on the actions of managers that were successful within the context of the organization's own culture. In such cases learning from competition and evaluating performance across organizations is not able to establish objective standards for managing within the unique culture of one's own organization and thus "adapting" is a superior approach than "adopting" best practice (HP Corporate Quality, 1987).

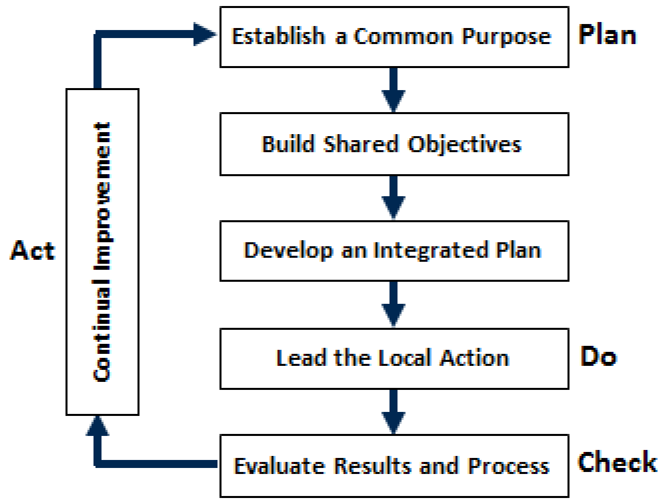

FIGURE 18: HP Process of Management Model

Systems thinking perceives and formulates mental models of interrelated processes as a holistic system as described by Peter M. Senge in his 1990 book, *The Fifth Discipline: The Art and Practice of the Learning Organization* (Senge, 2006). Understanding the dynamics of this systems model is an act of organizational learning which Chris Argyris and Donald Schön referred to as "double loop learning" (Argyris & Schön, 1974; Argyris, 1957; Argyris, 1962; Argyris, 1964; Argyris, 1965). The original statement of "double-loop learning" and the distinction between "espoused theory" and "theory-in-action" were initially described by Argyris and Schön in their 1974 book, *Theory in Practice*. According to them, a "theory of action" is first of all an espoused theory and possesses the "general properties…that all theories share and the most general criteria that apply to it–such as generality, centrality and simplicity – are criteria applied to all theories" (Argyris & Schön, 1974, p. 4). The critical distinction between these two theoretical constructs is that "theories of action" govern actual behavior within organizations and tend to be tacit structures while the espoused theories are descriptions of what we think we do or would like others to do, rather than describing what actually occurs. Alternatively, theories in action "contain assumptions about self, others, and the environment – these assumptions constitute a microcosm of science in everyday life" (Argyris & Schön, 1974, p. 30). When someone is asked to explain their reason for acting, they normally respond with an espoused theory; however, when one observes what actually controls their daily activities it is the "theory-in-use" or action theory (Argyris & Schön, 1974, pp. 6-7). How does this relate to the process of organizational learning?

According to Argyris, learning occurs in two "loops" that he labels "double-loop-learning" and learning happens when there is a disconnect between intention and outcome–in other words when there is a mistake, error or something goes wrong. Thus, learning involves the detection and correction of errors (Argyris & Schön, 1978, p. 2). When an individual just applies an espoused theory with its implicit goals, values and operating rules without questioning Argyris and Schön describe this state as "single-loop learning" which occurs in alignment of individual actions to the governing principles and theories. However, an alternative to this compliance approach to daily management with alignment to the basic rules occurs in what they have designated as "double-loop learning." "Double-loop learning" challenges the governing principles, assumptions and rules and results in correction or modification of the organization's fundamental policies, norms, and objectives–a shift in strategy occurs through the testing of the hypotheses under which the organization has been established and governed. Thus, by questioning core principles, theories and assumptions of organizations requires people to overcome the natural defensive behavior which occurs when fundamental beliefs are questioned. This model of "double-loop learning" is illustrated in Figure 19 (Argyris & Schön, 1974; Argyris, 1957; Argyris, 1962; Argyris, 1964; Argyris, 1965).

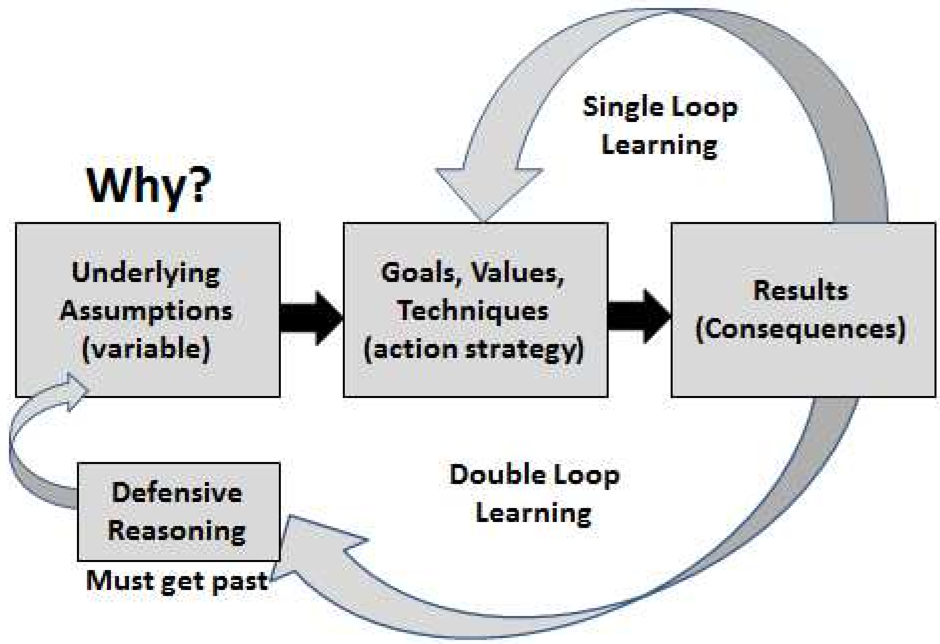

FIGURE 19: Double-Loop Learning Process

Thus, according to Dewey, Argyris and Schön, learning is a continuing process in the pursuit of knowledge. Knowledge is the object of the process of knowing. An epistemological pursuit of knowledge at the ultimate level is a pursuit for profound knowledge. Dewey and Bentley wrote *Knowing and the Known* in 1949 and thereby advanced learning theory into the discipline of psychology. Argyris and Schön captured the meaning of learning in every day experience in the profane activities of people and encouraged a deeper look into the critical meaning that lies behind the routine experiences of life. These thinking patterns open the way for a reframing of Deming's System of Profound Knowledge into a Theory of Profound Knowledge as grounded by the thinking patterns that emerge from the research revealed during the inquiry of this chapter.

CHAPTER V

A GROUNDED THEORY OF PROFOUND KNOWLEDGE: PURPOSEFUL TRANSFORMATION FROM CONTROL TO PREDICTION

This chapter extrapolates from the thinking kernel that was embedded in the system of profound knowledge proposed by Deming and its related historical intellectual contributions A restructured and comprehensive definition of the scientific approach will be used to develop a theory of profound knowledge based on grounded research. This chapter identifies contemporary contributions to the intellectual development of that theory and presents a strategic model for how it should be implemented in practice.

An integrated system of decision models will encourage achievement of purposeful transformation in the Bayesian moment to accomplish the prioritized strategic objectives of an organization and will provide the basis for proposed research in the post-dissertation phase of this research, which will address the practical applications of the new theory in the EDM function of organizations.

5.1 Axiomatic Definitions

As a starting point for this task, the following terms will be considered axiomatic and are defined here to establish a common meaning which will be used in subsequent discussions.

5.1.1 Strategic Change

The conscious restructuring of an organization's purpose, policies, processes, infrastructure, and/or core competences in order to achieve either a desired state or an increased level of operational control over its performance outcomes. Strategic change projects focus organizational resources on achieving a common, systemic goal through coordinated, shared actions for the mutual benefit of stakeholders. These purposeful changes are intended to deliver increased capabilities that extend the organization's resource effectiveness and/or efficiency.

5.1.2 Transformational Decisions

This term refers to executive decisions regarding strategic change that are based on considerations of all the dimensions of profound knowledge and result in the shift of organizational performance to a new level of effectiveness for control of its operational system. Transformation of this type can be either revolutionary (radical) or evolutionary (incremental), depending upon the nature of the strategic change and the speed required for its implementation. Predictable permanence and achievement of stable capability, as well as higher-level performance, beyond what the organization previously was attaining, are expected with transformation.

5.1.3 Bounded Rationality

Executive decisions must be made under conditions of what Simon called bounded rationality. This state of decision capability constricts decision quality whenever three conditions occur concurrently. First, the relative truth or falsehood of premises is not known definitively and cannot be determined with the quality of the data at hand. Second, the time available to make the decision is constrained so that a comprehensive assessment cannot be made. Finally, the competence or skill of the decision maker is limited (Simon, 1945; Wieck, 1995). When these conditions occur, then "facts give way to values, computation gives way to judgment, and sensation is displaced by ideology, all without the [decision maker] necessarily being the wiser for these shifts" (Weick, 1995). In the face of such circumstances, common sense overrules the rational judgment of Kahneman's System 2 thinking and System 1 emotive decisions are generated (Cite)–usually with an undue influence based on personal opinion. Under such circumstances, Simon contended that a decision cannot be optimized but rather that a decision maker "satisfices–looks for a course of action that is satisfactory or "good enough," based on the knowledge of the situation at hand (Simon, 1945, p. 119).

5.1.4 Situational Awareness

This involves a state of knowledge that is based on the ability of an observer to remain alert to relative shifts in the current situation's operational environment or ecosystem. This entails a heightened sensitivity to changes in circumstances that surround the current business or work process. Awareness of the current state, or living alertly in the moment, requires the ability to perceive change in environmental elements with respect to time and space, comprehension of the meanings in the current state, and projection of a new state after an operational variable has changed. Situational awareness creates knowledge that is actionable and it "is about the knowledge state that's achieved–either knowledge of current data elements or inferences drawn from these data, or predictions that can be made using these inferences" (Klein, Moon, & Hoffman, 2006, p. 71). Situational awareness also relates to a mental model that facilitates the recognition of in-state changes, such as the observe-orient-decide-act model that was created by Colonel John T. Boyd; it refers to a process that fighter pilots can employ to maintain vigilance and their capacity to act rapidly and react to stimuli in real-time aerial combat situations (Watson, 2005, pp. 126-128).

5.1.5 Sense-Making

The ability to understand the meaning hidden within data that is observed under ambiguous conditions (Simon, 1945, pp. 92-93). Weick (1995) provides the following description of sense-making:

> How can I know what we did until I see what we produced? The dominance of retrospect in sense-making is a major reason why students of sense-making find forecasting, contingency planning, strategic planning, and other magical probes in the future wasteful and misleading if they are decoupled from reflective action and history (p. 106).

Thus, foresight without both hindsight and insight leads to irresponsible decision making. Alternatively, it can be said that guessing leads to profane knowledge in pursuit of common sense. Sense-making relies on the same assumptions that develop through insight during a Bayesian moment transformation.

5.1.6 Causal Coupling

Deming quoted Lewis' book, *Mind and the World Order*, saying, "Knowledge has temporal spread" (Deming, 1994, p. 106) Simon noted, "…only those factors that are most closely connected with the decision in cause and time can be [properly] taken into consideration [in decision making]" (Deming, 1994, p. 95) One consequence of bounded rationality and its limitation related to the decision maker's ability to clarify the situation is that he or she will tend to "treat situations as only loosely connected to each other–most of the facts of the real world have no great relevance to any single situation and the most significant chains of causes and consequences are short and simple" (Deming, 1994, p. 95) Weick (1976) built on Simon's concept, defining "loosely coupled systems" (pp. 1-9) as those which have little interaction with or knowledge of the other components; in contrast, a tightly coupled system has direct linkages that are associated closely with proximity in time, space, and performance outcomes. Thus, causal coupling relates to the ability of the decision maker to grasp or perceive the relationship among events and their consequences. A general theory of loose coupling has been proposed by J.

Douglas Orton (1962-) and Weick (Orton & Weick, 1990, pp. 203-223).

5.1.7 Dynamic Capability

This is an organization's ability to maintain relevance of its capabilities as changes dynamically occur in its environment or ecosystem. According to Teece, this requires a "capacity (1) to sense and shape opportunities and threats, (2) to seize opportunities, and (3) to maintain competitiveness through enhancing, combining, protecting, and when necessary, reconfiguring the business enterprise's tangible and intangible assets" (Teece, 2009, p. 4). The ability to reconfigure itself based on situation awareness and sense-making is a critical competency for successful executives operating in the Bayesian moment, where such externalities may stimulate the need for rapid decision making under conditions of bounded rationality.

5.1.8 Unintended Consequences

Merton popularized this term in the 1930s. It applies to achieving unexpected or unforeseen outcomes when executing a purposeful action to attain a chosen or desired end state or result. He defined "purposeful action" (Merton, 1936, pp. 894-904), or any action which drives a search for profound knowledge by an EDM process as "action that involves motives and consequently a choice between various alternatives" (Merton, 1936, p. 895). Shewhart had sought to avoid the results of unintended consequences by developing greater confidence in prediction of outcomes by using control charts. They were intended to improve quality by supporting sense-making related to observations of dynamic situations through the establishment of causal coupling among alternatives that predictively produced positive results with a high degree of probability while also avoiding unintended consequences.

5.1.9 Functional Maturity

Merton postulated a common intellectual misconception, which he called an "assumption of historical contemporaneity," meaning that "all cultural products existing at the same moment of history have the same degree of maturity" (Merton, 1949, p. 454). This can be related to his defintions of functions as manifest (obvious capability), latent (unnoticed capabilty), and dysfunctional (when the functional actions fail to deliver the intended purpose because those actions are not operating normally). When causaility is applied to operating processes, Shewhart's ideas fit with Merton's concepts of sociological functions. For instance, when there is a manifest function operating dysfunctionally, then it can be assumed that the issue is due to an assignable or special cause of variation. However, when a latent function is operating dysfunctionally, then it is likely that an unassignable or common cause of variation exists. Not all functions or processes operate at the same level of maturity at any particular point in time, so their performance in the Bayesian moment requires development of profound knowledge of not only their past states and current states but also the potential future states to which they might evolve. Thus, predictive analytics must be used to determine the probablistic nature of the processes' future capability.

5.1.10 Willful Ignorance

Willful ignorance summarizes the qualifying characteristics of a state of learning, called profane knowledge (Weisberg, 2014). The individual in this state either exhibits a condition of unconscious incompetence or conscious incompetence (Broadwell, 1969). This results in a state of mindlessness that is induced by the reliance on profane knowledge for decision making (Langer, 1989). In this mindless mental state–an ongoing practice in decision making--the decision maker either consciously or unconsciously ignores or remains closed to consideration of any inputs that conflict with his or her prevalent mental model regarding belief in the inherent state of reality, therefore deny the opportunity for sense-making. The state of willful ignorance is characterized by a passive pursuit of sense-making that is based on superficial situational awareness. Willful ignorance is fueled by over reliance on Kahneman's continuously operating, emotively-driven System 1 thinking process and is unfettered by any constraints associated with

System 2's logically deduced rules. "The success of System 1 is the coherence of the story it manages to create" (Kahneman, 2011, p. 85). This condition of willful ignorance often is supplemented by "executive excusing" when the predicted potential or future states fail to materialize and the previously coherent story is reduced to incoherence (Watson, 2018).

5.1.11 Purposeful Enlightenment

This term summarizes the basic qualifying characteristic of a state of learning, called profound knowledge. In this situation, the individual either exhibits a mental state of conscious competence or unconscious competence in his or her approach to knowledge-related work. Mindfulness is achieved based on an active pursuit of profound knowledge that supports decision making. When this occurs, decision making may be perceived as an ongoing practice, where the individual either consciously or unconsciously pursues or remains open to consideration of all inputs that conflict with his or her prevalent mental model (Broadwell, 1969). Therefore, this state of purposeful enlightenment is achieved through an active pursuit of sense-making based on sound situational awareness that develops rational System 2 rules, establishing and defining the set of boundary conditions that advise the emotional System 1 decision-making process in order to "activate ideas" (Kahneman, 2011, p. 5).

5.2 Conceptualizing the Theory of Profound Knowledge

What is theory and what must be included to consider a body of knowledge to accept it as a theory? Theory is an a priori framework of a coherent set of propositions or principles that explain or predict phenomena from experience. Theory may be testable and verifiable through the scientific method by researching the set of definitions, hypotheses, and logical propositions on which the theory has been formulated. The operational definitions of the key terms with descriptions of their meaning is the first step required for developing theory. In the case of the theory of profound knowledge, this means that a definition for profound knowledge and its logical opposite, profane knowledge, are necessary and must be decomposed into the elements that can be tested and/or verified through scientifically based research.

5.2.1 Operational Definition of the Properties of Profound Knowledge

Profound knowledge is defined as enduring knowledge of phenomena that may be characterized with probabilistic interpretation by understanding potential process performance outcomes. It is obtained objectively by investigating past performance with statistical methods. The resultant statistical understanding of the nature of real-world process behavior permits future states of performance to be predicted with some probability. This equates to System 2 types of knowledge according to Kahneman.

5.2.2 Operational Definition of the Properties of Profane Knowledge

Here, superficial or ordinary knowledge is based on intuitive interpretation and understanding of potential process results that have been obtained subjectively. Profane knowledge assesses the apparent state of reality by observing and applying methods of common sense to arrive at a theory of reality that is based on opinions rather than objective data analysis. This aligns with the emotional outcome based on personal mental models that is not supported by analytical methods of science described by Kahneman as System 1.

5.2.3 Comparison of Profound Knowledge With Profane Knowledge

The scientific method is based on the principle of testing hypotheses. Null and alternative hypotheses are used to reflect logical opposites, and rejecting the null hypothesis confirms the alternative hypothesis. Thus, the opposites of profound and profane knowledge must be postulated in order to have a sound basis for the new theory of profound knowledge. The distinguishing characteristics of profane and profound knowledge are compared and contrasted in Table 13 (Watson, 2017, pp. 23-25).

Characteristic Category	Profane Knowledge	Profound Knowledge
Degree of Knowledge	Surface knowledge (naïve)	Deep knowledge (enlightenment)
Explicitness of Function	Manifest functionality	Latent functionality
Discovery Mechanism	Explicit discovery	Tacit discovery
Predictive Function	Linear in nature	Systemic in nature
Analytical Model	Focused on averages	Manages the variation
Human Considerations	Ignores human factors	Understands human nature
Data Approach	Enumerative use of data	Analytic use of data
Propositional Agreement	Convergent	Divergent
Methodological Validation	Backed by tribal lore	Backed by science
Decision Criteria	Based on common sense	Based on uncommon logic
Decision Mindset	Mindless reflection	Mindful insight
Speed of Decision Making	Reactive/rapid decisions	Logical/deliberate decisions
Thinking Process	Driven by “System 1” thinking	Driven by “System 2” thinking

TABLE 13: Comparative Characteristics of Profane and Profound Knowledge

The proposed theory of profound knowledge seeks to elucidate the purpose that supported the four categories in Deming’s proposed system of profound knowledge. It moves beyond the investigation of special causes of variation to understand what must be changed in the system architecture to drive transformative change to the system as a whole or to transform the contributors constraining the system’s performance as a result of common cause variation. The Deming approach focused on inquiries into eliminating special cause variation that are deviations from standard work, defining the system design and specifies the way it should work to become predictable (Deming, 1994, pp. 201-202). This approach to variation management improves the entire system, except for the unintended consequences of design shortfalls associated with the delivery of the desired purpose. Eliminating problems in the design requires focusing on the reduction of the system's common causes of variation as well as the effect of latent variables, which were not visible to the original system designers. Deming observed, "…once you reach statistical process control" (removal of all special cause variation so that only common causes of variation remain). Then "the difficult problem commences–improve the system" (Deming, 1994, p. 202).

Thus, managing common cause variation is the approach required to improve any system over the long term in order to achieve transformation, a breakthrough or disruptive change in the system's operation. Dorian Shainin called such latent variables "Red Xs." Their impact on process performance is not made obvious by statistical analysis and estimation because it only is seen in the noise and residual effects that are not explained by an analytical model. Therefore, its source is not readily identifiable (Shainin, 1993, pp. 433-448; Shainin, 2012, pp. 171-183). Such factors are "unknown–unknowns." It is often possible to trace such factors back to the design process and discover that the source of their origin is decisions based on profane knowledge because the system requirements were established more by ad hoc agreement than scientific inquiry into customer needs.

5.2.4 Elements of Profound Knowledge

How can the elements of profound knowledge be defined operationally based on the four components of the system of profound knowledge proposed by Deming? Discovery of profound knowledge occurs when the four integrated elements are practiced in a disciplined, coordinated manner to establish boundary conditions or rules for conducting work. They parallel the system of profound knowledge when slightly modified categorical labels are applied, as described below:

5.2.4.1 Integration of a system architecture. This is the understanding the interrelationships among all of the system components that influence the way that work is being done and the critical decisions that are being made to generate productive outcomes, known as process management.

5.2.4.2 Statistical thinking about variation. Knowledge of the system's operation is disclosed through a study of variation in the performance outcomes and tracking that variation back to its source as either a special or common cause for effecting improvement. This requires reduction and control of the sources of variation called statistical thinking.

5.2.4.3 Learning about profound knowledge. Profound knowledge comes from observing work, speculating on the theory about the associated work operations, and testing and confirming the theory of measurement observations, as well as the applications of the theory related to the continuous pursuit of knowledge.

5.2.4.4 Understanding psychology. Managing human behavior requires reflective mindfulness, understanding, interpretation, motivation, development, and coordination to achieve results. A collaborative culture must be created through participative management.

Achieving profound knowledge consistently requires designing functional systems to reduce the common cause variation that has been designed into processes. This approach aligns the entire system architecture with achieving its common objectives and uses system resources in an integrated manner that simultaneously is coordinated across the organization's functional areas and major business processes. This occurs when managing by quality is the common approach of business leaders and comprehensive quality performance is the organizational strategy.

5.3 Dissecting the Theory of Profound Knowledge

Theoretical and practical aspects of the theory of profound knowledge are listed below (see Table 14) (Watson, 2018):

	Theoretical Aspects	Practical Aspects
Subject	Theory of profound knowledge	Strategy management
Responsible	Decision maker	Executive function
Motivation	Organizational transformation	Strategic change
Operational Definition of Principal Property	Profound knowledge	Predictable outcome
Operational Definition of Logical Alternative	Profane knowledge	Unpredictable outcomes associated with chance results of complexity
Criteria for Negation	Causal coupling	Scientific method
Component Elements	Integration of a system architecture	Process management
	Statistical thinking about variation	Statistical thinking
	Learning about profound knowledge	Measurement analysis
	Understanding psychology	Collaborative culture
Execution Model	Process of management	Strategy management process

TABLE 14: Summary of the Theory of Profound Knowledge

Each of the theoretical components of profound knowledge has a practical parallel. The practical aspects shown in this table translate the theoretical terms into real-world elements. As a whole, this theory and its practical expression represent a learning experience for the organization. If investigation of data using probing questions produces understanding and knowledge, then deep learning is achieved and profound knowledge is revealed. A system that generates profound knowledge enables decision makers to drive their organizational learning and shift productive performance to new levels that produce learning and become a basis for executing change projects that create transformation (Watson, 2017, pp. 39-40).

This transformation is stimulated by learning, and structured inquiry develops profound knowledge in organizations. Table 15 presents one way of decomposing the requirements for learning that are observed through routine experience (e.g., the idea of "single-loop learning" from Argyris and Schön to uncover the deeper meaning that lies behind the routine or the profound knowledge (as uncovered by Argyris' and Schön's (1974) "double-loop learning" process which provides the fundamental framework of theory as applied in action (p. 4).

Hierarchy of Means—Requirements for Learning	Diagnostic Journey—Sorting Through Profane Knowledge	Remedial Journey—Seeking Profound Knowledge
Laws and Theory	Situational awareness	Systems analysis
Principles and Methods	Sense-making	Probability and variation
Techniques and Tools	Exploratory data analysis	Process of inquiry
Applications and Facts	Heuristic analysis	Psychology and human factors

TABLE 15: Profound Knowledge and the Requirements for Learning

Deming alluded to the significance of learning being a core concept when he introduced the rationale for his change to the Japanese PDCA Control Cycle, substituting the study step for the check step. He called the revised model a "flow diagram for learning, and improvement of a product or process" (Deming, 1994, p. 131). He later spoke about this motivation for learning. "Joy in learning comes not so much from what is learned but from learning" (Deming, 1994, p. 145). In the Bayesian moment, learning occurs at the intersection of hindsight with insight and involves an innovative interpretation of the historical patterns (e.g., noticing the observable special and common causes of variation and identifying their sources), which defines a new way forward that transforms organizational behavior. This learning process represents a variation of the Argyris and Schön double-loop learning that generates a triple-loop learning system through the addition of strategic consideration. Drucker had observed that management must make the "ability to unlearn itself part of what a man learns. This requires that one learns by acquiring knowledge rather than simply by experience. It requires 'teaching' programs rather than 'training' programs" (Drucker, 1954, p. 268). Thus, this new configuration of the learning model identifies the important learning activities that are essential within the Bayesian moment. With the third loop added to the model, each of the three loops addresses one of three questions previously raised regarding the focus of the organization on what to improve and as well as on a different aspect of the engagement with work: results, actions, assumptions, and context. These are relevant focus areas for different process assessors. A revised structure for the Argyris and Schön double-loop learning model is shown in Table 16 and was described previously in the graphically mental model, Figure 19 in Chapter IV (Watson, 2012, p. 36).

Learning Loop	Objective	Question Raised	Assessor
Single Loop	Problem solving	Am I doing things right?	Workers
Double Loop	Priority review	Are we doing the right things?	Supervisors
Triple Loop	Strategic direction	How do we decide what is right?	Executives

TABLE 16: Decomposition of the Triple-Loop Learning Model

This triple-loop learning process requires a sequential and persistent inquiry to produce profound knowledge and be capable of transforming the organization's systems from the state observed by hindsight into the state desired by foresight (see Figure 20) (Watson, 1994; Watson, 2012, pp. 35-38).

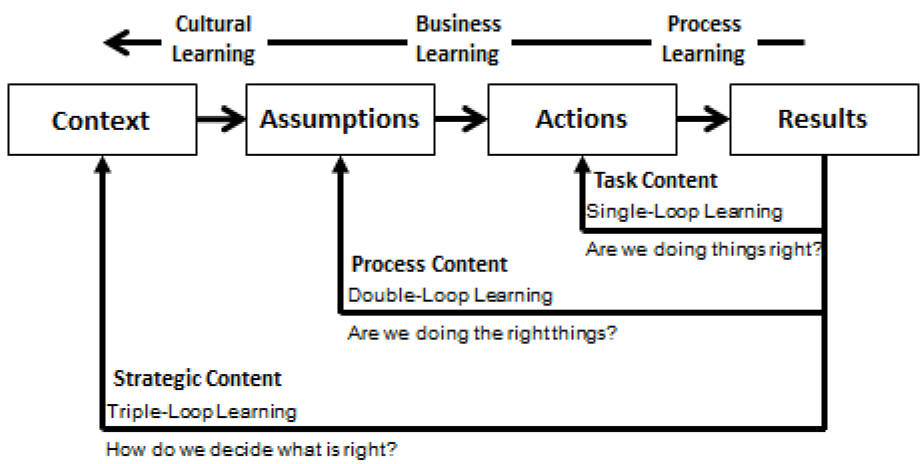

FIGURE 20: Triple-Loop Learning Process

This implies that Deming's "study" concept is actually valid but is transferred as a responsibility across the organization into different levels in order to achieve different objectives, rather than as part of the inquiry processes associated with the Shewhart Cycle or Japanese PDCA Control Cycle. The task is to find the answer to problems that upset the productive flow of standard work by learning how to operate processes better. Supervisors must focus on the prioritization of the tasks that are being performed and the methods that are used for improvement of the work processes; this requires that supervisors concentrate on how to make work activities flow across the business processes better. Executives need to focus on creation of the strategic direction within which its critical tasks can be prioritized. Thus, learning must be integrated across all levels in order to achieve a "learning organization" as characterized by Peter M. Senge (1947-) in his 1990 book, *The Fifth Discipline: The Art and Practice of the Learning Organization* (Senge, 2006).

Incorporating this triple-loop learning into the Bayesian moment, as illustrated in Figure 21, enables decision makers to have clearer insight into what must change in the system so they can make better choices; the profound knowledge that triple-loop learning generates improves fosters an appropriate mindset for decision making. This learning process must be embedded in the activities of the Bayesian moment. How does the Bayesian moment mental model describe the integration of these concepts?

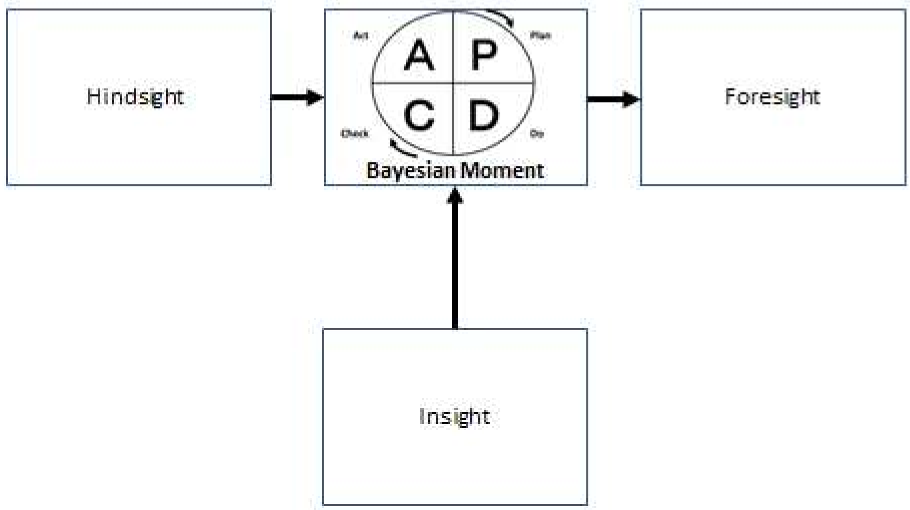

FIGURE 21: Bayesian Moment Model for Organizational Transformation

5.4 Modeling the Theory of Profound Knowledge

The application of the theory of profound knowledge occurs in the Bayesian moment when an organization replaces its historical legacy and embraces a new way of working. The Bayesian moment therefore provides a model for conducting scientific inquiries during the insight phase, when transitioning from hindsight to foresight. The Japanese PDCA Control Cycle describes a scientific approach that achieves future strategic aims after the necessary learning has occurred. A mindful organization that is attentive to studying how to improve will apply a process for structured analytics in the Bayesian moment to create Nonaka's (2000) state of BA (pp. 5-34).

In Figure 21 the Japanese PDCA Control Cycle is used rather than the spurious PDSA model proposed by Deming (1994) in *The New Economics* as he ruminated about the system of profound knowledge. Therefore, a leadership task associated with the Bayesian moment is the management of change from the old way of doing things to the new, improved way. The challenge of this task is to transition from the strategic dialog in which an organization defines its future work intentions to the achievement of an actionable approach for executing those intentions. This probably is what Deming meant to imply when he said, "It is management's responsibility to look ahead, predict, change the product, [and] keep the plant in operation" (Deming, 1994, p. 18). Deming focused on two issues, "How can knowledge be gained?" and "By what means can knowledge acquisition occur?" He also asked, "By what method could new leaders bring improvement in living?" (Deming, 1994, p. 1). Improvement efforts among leaders differ from those that exist within their front-line operations. Leadership applies additional resources to increase capability, capacity, or the competence of its operations. Addressing the common cause system raises performance levels and is achieved through standard work processes and the pursuit of breakthrough improvement. On the other hand, front-line operations focus on the efficient and economical delivery of effective outcomes that meet or exceed targeted results.

The Bayesian moment mental model offers a solution to Deming's questions. During the Bayesian moment, management's attention is directed to identifying those projects that will transform the organization to achieve a desired future state that has been designed for execution by front-line staff using "BA." This becomes the basis for the executive decision to choose a particular improvement path for moving toward the direction of the desired state of foresight.

5.5 Principles of the Theory of Profound Knowledge

The theory of profound knowledge is summarized in the following principles that are based on an operationally based definition of quality, the persistent pursuit of goodness coupled tightly with a relentless avoidance of badness. The theory identifies the elements of "badness" as those aspects of profane knowledge that must be avoided while pursuing profound knowledge in order to embrace "goodness" during the period that a leader is transitioning his or her organization through the transformation of the Bayesian moment. Three principles may be postulated regarding this leadership activity.

- Principle 1: Leadership must engage the entire productive system in the transformation.
- Principle 2: Statistical methods help establish stability and define change imperatives.
- Principle 3: Employee engagement through action learning yields a collaborative result.

These three principles integrate the four elements of the system of profound knowledge; the two categories, profound and profane knowledge; those categories' defining properties; and the activities that the executive function must take after learning the nature of profound knowledge. This drives the transformation from the organizations historical state of existence to a new state that is more appropriate for its required future operations.

5.6 Observations Regarding the Theory of Profound Knowledge

This completes the formalized definition of the theory of profound knowledge based on the system of profound knowledge that was postulated by Deming. It results in an understanding of the way that knowledge can be pursued in a learning process to support objective development of strategic choices by executives in order to increase the quality of organizational performance. The next chapter of this dissertation will assess the validity and reasonableness of this theory through a survey-based inquiry, involving an expert panel consisting of academics and experienced practitioners.

CHAPTER VI

CONFIRMATORY VALIDATION OF THE PROPOSED GROUNDED THEORY: A SURVEY OF ACADEMIC AND PRACTITIONER SUBJECT MATTER EXPERTS

As Glasser observed, grounded research cannot be scientifically verified (Glasser, 1998, pp. 4, 102-105), but it can be validated in experience that parallels the action learning approach that was proposed by Argyris and Schön (1974, p. 30). Glasser (1998) suggested three criteria for validation of grounded theories proposed for consideration (p. 18). The first was fit, described by the question, “How well does the conceptual theory express the pattern that it seeks to represent?” The second criterion was workability, answering the questions “How well does the conceptual theory relate to the research hypotheses?” and “Does it sufficiently account for and resolve the concerns of participants in the survey?” Finally, relevance must be addressed by asking, “How well does the conceptual theory relate to important concerns of the survey participants?” The survey associated with this dissertation was conducted using the web-based software, Survey Monkey®. The survey was distributed to 50 individuals who were selected for their recognized professionalism, either as academic members of the International Academy for Quality or as qualified Master Black Belts selected from students that the researcher had taught over the past 20 years. This chapter describes the survey content and reports approved by the Oklahoma State University Institutional Review Board (IRB).

6.1 Demographic Information Gathered in the Survey

Participate in the survey were divided evenly among academics and practitioners to promote balanced representation in the survey findings. Four demographic areas were used to classify the qualifications of participants, and they are listed below along with the options that were provided:

- Age group: under 40, 40-60, or over 60.
- Professional category: academic or practitioner.
- Highest degree attained: bachelors, masters, or doctorate.
- Professional qualification: professional engineer (or equivalent), master black belt or (equivalent), other, or none.

This set of demographic questions was used as categorical discriminants to compare the two cohorts regarding their assessments of the statements of affirmation so that the validity of the proposed theory could be evaluated.

6.2 Assessment Statements for Validation of the Theory

The information below describes the instructions that the respondents received for assessing the statements of affirmation included in the survey:

The participants received appropriate background content from the dissertation to provide a foundation for the survey. Then the participants were asked to judge the seven statements of affirmation using the same response scale and supporting comments were solicited. The statements of affirmation were augmented with appropriate operational definition to clarify the key terms to focus the participants' analysis.

6.2.1 Scale for Recording Judgment

The following instructions and the associated scale shown in Table 17 were used by the respondents to rate the statements of affirmation. This information appeared below each statement of affirmation and its operational definition.

"Please indicate your strength of agreement with the above statement by selecting the appropriate level of agreement on the following scale: Scale of Agreement."

Most strongly disagree	Strongly disagree	Weakly disagree	Neutral	Weakly agree	Strongly agree	Most strongly agree
1	2	3	4	5	6	7

TABLE 17: Fully Anchored Judgment Scale Used for Survey Responses

6.2.2 Statement to Affirm #1

"The stated assumptions of the dissertation possess a necessary and sufficient degree of validity.

Operational Definition of Key Terms:

- Validity: The extent to which the assumptions support the fundamental logic that is required for initiation of the research question."

6.2.3 Statement to Affirm #2

"Operational definitions proposed in the dissertation provide ambiguity-free meaning and identify the scope of the term defined.

Operational Definition of Key Terms:

- Clarity: Clearness or lucidity in explanation so that perception and understanding are readily communicated; freedom from confusion, ambiguity, or indistinctness in meaning."

6.2.4 Statement to Affirm #3

"The research question posed in the dissertation is exceptionally innovative compared to the prior body of knowledge.

Operational Definition of Key Terms:

- Innovativeness: The introduction of a new idea, method or theory that meets new requirements, satisfies unarticulated needs, or expands existing knowledge."

6.2.5 Statement to Affirm #4

"The identified historical trends cited as 'thinking pathways' define relevant subjects for inquiry in the literature search.

Operational Definition of Key Terms:

- Relevance: Pertinent to the matter at hand, important for the full understanding of the development of the concepts and are related to the subject at hand."

6.2.6 Statement to Affirm #5

"The background literature investigation represents a complete enumeration and description of the key contributions for each of the thinking pathways that are identified as contributing to the theory of profound knowledge.

Operational Definition of Key Terms:

- Completeness: A comprehensive, inclusive enumeration of parts, items, or elements that lacks nothing; an exhaustive compilation of the whole or the entire subset of components that contains all appropriate parts or rational sub-groups.

- Significance: Items that are worthy of attention due to their importance, seriousness, gravity, or consequences".

6.2.7 Statement to Affirm #6

"The proposed theory of profound knowledge offers significant value in regard to the explanation of the transformation process, and it represents a significant contribution to the advancement of the system of profound knowledge as proposed by Deming.

Operational Definition of Key Terms:

- Value**:** The degree of worthiness or usefulness of something; benefit may be gained through the relative merit or utility of a proposition, item, or belief."

6.2.8 Statement to Affirm #7

"The theory of profound knowledge presented in the dissertation is applicable to the advancement of the current practice of quality management and will be significant for developing further advances to the quality management body of knowledge."

Operational Definition of Key Terms:

- Applicability: The proposed theory represents a systematic approach that involves the practical application of relevant, suitable knowledge that provides an approach to the substantial issue of estimating future states of organizational performance, defining how to effect the transformation, and identifying the system and human factors that will influence the transformation.

- Quality: The persistent pursuit of goodness, coupled tightly with the relentless avoidance of badness, as determined from the perspective of the ultimate customer.

- Quality Management: The administration and oversight of the activities and the tasks necessary to design, develop, and maintain a desired level of performance excellence necessary to achieve quality in the content delivered to customers and the process by which that content is delivered."

6.3 Survey Analysis Methodology

Survey responses for those seven statements of affirmation were compared for the two cohorts to determine the degree of correspondence between their reactions to each of the specific statements. A table of comparison for the raw responses was calculated for each item, and it included the mean, variance, and number of responses for teach category for that statement, as well as Cronbach's Alpha statistic.

Cronbach's Alpha was named for Lee J. Cronbach (1951), who lived from 1916 to 2001, who presented this methodology in 1951 (pp. 297-334). It is a statistical test of equivalence that indicates the expected correlation between two sets of data that measure the degree of agreement between respondent groups for same statement. It is used to determine the internal validity or consistency of responses in evaluation scores. It is a "reliability coefficient [that] determines whether the test designer was correct in expecting a certain collection of items to yield interpretable statements about individual differences" (Cronbach, 1951, p. 297).

The formula for the standardized Cronbach's alpha α_s is shown in the equation below, as used in

$$\alpha_s = \frac{p \cdot \bar{r}}{1 + (p-1) \cdot \bar{r}}$$

where

p = the total number of items (e.g., questions), and

$\bar{r}$ = the mean of Pearson correlation coefficients between all items

The statistic is a function of the number of items in a comparison, the average covariance in the responses between item-pairs, and the variance of the total score for that item. The expectation was that the scores of the academics and t practitioners would not be statistically significantly differ. Therefore, their collective response would be indicative of the population response for the degree of the strength of the sub-group responses.

What result for this statistical calculation indicates statistical relevance of the two cohorts' responses? Since the introduction of Cronbach's Alpha statistic, there has been some disagreement regarding how to interpret the meaning of the value it produces. A guideline to interpret the standardized form of the statistic was provided by Jose M. Cortina (1993), born in 1970, as shown in Table 18 (pp. 98-104). Based on that scale, the targeted level of reliability for demonstration of significance was determined to be at least 0.7 for each of the seven questions. Although some controversy exists in the interpretation of Cronbach's Alpha, this classification did become accepted in the psychometric community for exploratory research (Nunnally, 1978, pp. 202-220) and was deemed to fit this research acceptably well.

Cronbach's Alpha Score	Internal Consistency
Above 0.9	Excellent
0.8 to 0.9	Good
0.7 to 0.8	Acceptable
0.6 to 0.7	Questionable
0.5 to 0.6	Poor
Below 0.5	Unacceptable

TABLE 18: Levels of Significance for Interpretation of Cronbach's Alpha

In addition to reporting and interpreting the Cronbach Alpha for the question ratings, all text comments provided by the participants were analyzed.. Specific noteworthy comments will be discussed in the commentary section of this dissertation.

6.4 IRB Approval

Pursuant to the requirements of Title 45 Code of Federal Regulations Part 46 (45 CFR 46), Protection of Human Subjects (revised 15 January 2009), an application to review the research survey was submitted by the researcher to the Oklahoma State University IRB. Appendix A documents the application, Appendix B documents the survey, and Appendix C is the approval by the IRB to conduct the research.

CHAPTER VII

FINDINGS FROM THE SURVEY OF EXPERT PANELISTS: OBSERVATIONS REGARDING THE THEORY OF PROFOUND KNOWLEDGE

The survey was distributed to 50 individuals, who had been divided into two rational sub-groups with equal representation: academics and practitioners. The purpose of the expert panel survey was to validate the key concepts of the proposed theory of profound knowledge to determine its fit, workability, and relevance, as described by the questions presented in Chapter VI. Individual survey responses are reported in Appendix D. Observations related to the survey findings are presented in the following sections.

7.1 Response Rates and Demographics of Responders

There were 12 responses from each of the two research cohorts, which represents a 48% response rate. Table 19 summarizes the demographic profiles of the respondents.

Professional Category		Academic	Practitioner	Total
Number Replies		12	12	24/50 48%
Age Group	<40	1	2	3/24 12.5%
	40-60	5	7	12/24 50%
	>60	6	3	9/24 37.5%
Highest Degree	BA/BS	0	2	2/24 8.3%
	MA/MS	0	6	6/24 25%
	PhD	12	4	16/24 66.7%
Professional Qualification	PE	3	1	4/24 25%
	MBB	4	10	14/24 58.3%
	Other	1	0	1/24 4.1%
	None	4	1	5/24 20.8%

TABLE 19: Demographic Description of Expert-Panel Survey Respondents

7.2 Validation of Responses Using Cronbach's Alpha Statistic

As previously described in VI, Cronbach's Alpha assumes that all items use the same response scale for selection by the respondents and is used to estimate the consistency of the composite ranking scores of survey respondents. The critical value for Chronback's Alpha had been set at 0.70 for analysis of this study, A graphical display of the distribution of raw data responses is presented in Figure 22, and it illustrates that of the 168 responses provided, only 17 (10.2%) had a scalar rating below "6," which was associated with the choice, "Strongly Agree."

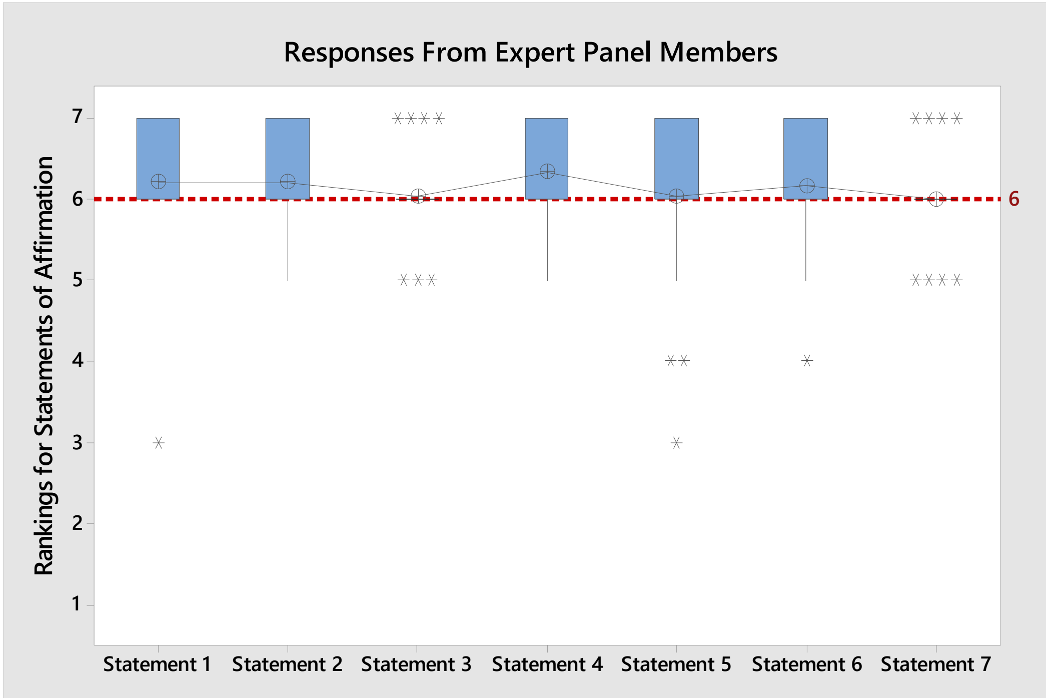

FIGURE 22: Distribution of Individual Responses by Statement of Affirmation

When Cronbach's Alpha was calculated for the overall response statistics the result was a score of 0.632, indicating questionable reliability. When the two respondent cohorts (academics and practitioners) were analyzed individually, different results were obtained. The Cronbach Alpha for the practitioners was 0.518, indicating poor reliability. However, the Cronbach Alpha calculated for the academics was 0.781, which indicated better reliability. Clearly, the lower level of reliability associated with the practitioners' responses was statistically significantly different than that of the academic respondents. These calculations are presented in Table 20 below:

Response Cohort Analyzed	Cronbach's Standardized Alpha	Conclusion Reached
Academic Response	0.781	Good Reliability
Practitioner Response	0.518	Poor Reliability
Total Survey Response	0.632	Questionable Reliability

TABLE 20: Analysis of Cronbach's Standardized Alpha Statistic

Although it is noteworthy that the entire survey response did not meet the established criterion for reliability, it is more important to observe how well the academic cohort fits the expectation for significance when compared to the practitioners' responses. In fact, it is this latter result that decreases the significance of the overall survey. This may be due to the academics' higher level of experience with analyzing and interpreting subjective, abstract mental models. Practitioners, on the other hand, have more experience related to analyzing and interpreting objective, observational physical models. This proposed conclusion was supported by some of the comments that were made by the respondents, and this will be evident as each of the seven survey statements of affirmation is reviewed in the following sections.

7.3 Statement of Affirmation #1: Response Ratings and Commentary—Validity of Assumptions

The assumptions identified in this dissertation were intended to establish a foundation for a theory of profound knowledge. Acceptance of their validity was an important initial step toward understanding the arguments that follow. Table 21 presents a summary of the respondent's answers to for this survey item.

Professional Category	Number of Responses (Percent of Professional Category or Total)		
	Academics	Practitioners	Total
Most Strongly Disagree=1	0 (0.0%)	0 (0.0%)	0 (0.0%)
Strongly Disagree=2	0 (0.0%)	0 (0.0%)	0 (0.0%)
Weakly Disagree=3	0 (0.0%)	1 (8.3%)	1 (4.2%)
Neutral = 4	0 (0.0%)	0 (0.0%)	0 (0.0%)
Weakly Agree=5	0 (0.0%)	0 (0.0%)	0 (0.0%)

Strongly Agree=6	10 (83.3%)	5 (41.7%)	15 (62.5%)
Most Strongly Agree=7	2 (16.7%)	6 (50.0%)	8 (33.3%)
Mean	6.167	6.25	6.208
Std. Dev.	389	1.382	0.833

TABLE 21: Respondent Ratings for Statement of Affirmation #1: Assumption of Validity

Note that the mean of the practitioners' rating scores is higher than that of the academics; however, the standard deviation is much larger. This occurred because a single practitioner rated this item "3," "weakly disagree." However, in this participant's comment, he or she stated, "This misses the point that validity is logically or factually sound. How do assumptions fit into the definition of validity?" The statement that respondents were requested to affirm asked whether the assumptions possessed a necessary and sufficient validity, defined as "the extent to which the assumptions support the fundamental logic that is required for initiation of the research question." This respondent ignored that operational definition and seemed to be seeking an objective, factual grounding of the assumptions.

7.4 Statement of Affirmation #2: Response Ratings and Commentary—Ambiguity-Free Operational Definitions

The respondents had similar assessments regarding the affirmation of ambiguity-free operational definitions. The practitioners had a slightly higher score, but that difference was not considered to be statistically significantly different because the standard deviations for the two groups were almost equal.

One respondent "strongly agreed" and observed that "Deming had stressed the importance of operational definitions in dealing with any metric. He had also emphasized that there is no 'true' value of anything–it all depends on the operational definition."

One of the two respondents who weakly agreed felt that operational definitions should be "measurable;" however, this was not included in the way that term had been defined in the survey's definition of clarity, "clearness or lucidity in explanation so that perception and understanding are readily communicated; freedom from confusion, ambiguity, or indistinctness in meaning." The emphasis in this particular response should have focused on the semantic meaning of the operational definitions.

Table 22 summarizes respondent's answers. The overall result was very positive, indicating that both cohorts agreed with the clarity of the operational definitions.

Professional Category	Number of Responses (Percent of Professional Category or Total)		
	Academics	Practitioners	Total
Most Strongly Disagree=1	0 (0.0%)	0 (0.0%)	0 (0.0%)
Strongly Disagree=2	0 (0.0%)	0 (0.0%)	0 (0.0%)
Weakly Disagree=3	0 (0.0%)	0 (0.0%)	0 (0.0%)
Neutral = 4	0 (0.0%)	0 (0.0%)	0 (0.0%)
Weakly Agree=5	1 (8.3%)	1 (8.3%)	2 (8.3%)
Strongly Agree=6	9 (75.0%)	6 (50.0%)	15 (62.5%)
Most Strongly Agree=7	2 (16.7%)	5 (41.7%)	7 (29.2%)
Mean	6.083	6.333	6.208
Std. Dev.	0.515	0.651	0.588

TABLE 22: Respondent Ratings for Statement of Affirmation #2: Ambiguity-Free Operational Definitions

7.5 Statement of Affirmation #3: Response Ratings and Commentary—Research Innovativeness

There was a noticeable difference between the rating of the academics and practitioners related to this statement. The practitioners rated it higher than the academics did. This is likely to be due to the academics' greater familiarity with the theoretical components than would be anticipated from the practitioners, who are believed to be more focused on pragmatic applications when applying theory to practice. However, consistency, as indicated by the standard deviation, within the two groups was roughly equivalent, indicating that the cohorts' judgments were similar. Table 23 presents the responses.

Professional Category	Number of Responses (Percent of Professional Category or Total)		
	Academics	Practitioners	Total
Most Strongly Disagree=1	0 (0.0%)	0 (0.0%)	0 (0.0%)
Strongly Disagree=2	0 (0.0%)	0 (0.0%)	0 (0.0%)
Weakly Disagree=3	0 (0.0%)	0 (0.0%)	0 (0.0%)
Neutral = 4	0 (0.0%)	0 (0.0%)	0 (0.0%)
Weakly Agree=5	3 (25.0%)	0 (0.0%)	3 (12.5%)
Strongly Agree=6	8 (66.7%)	9 (75.0%)	17 (70.8%)
Most Strongly Agree=7	1 (8.3%)	3 (25.0%)	4 (16.7%)
Mean	5.833	6.25	6.083
Std. Dev.	0.515	0.452	0.504

TABLE 23: Respondent Ratings for Statement of Affirmation #3: Research Innovativeness

The academics who rated this statement “weakly agree” did not offer any comments to explain their judgments. In fact, one of those two academics rated four of the responses as “weakly agree,” which constituted 25 percent of the total number of lower ratings. Thus, an assessment of these respondent ratings has been considered to have confirmed agreement with the statement of affirmation regarding innovativeness of this research.

7.6 Statement of Affirmation #4: Response Ratings and Commentary—Relevant Thinking Pathways

Table 24 indicates the degree of agreement related to this statement of affirmation. Comments for this item included “very extensive,” “full history,” “immense,” and “deep investigation and impressive list.” Although the mean of the practitioner’s ratings is higher than that of the academics, the standard deviations of the two cohorts were essentially equivalent.

Professional Category	Number of Responses (Percent of Professional Category or Total)		
	Academics	Practitioners	Total
Most Strongly Disagree=1	0 (0.0%)	0 (0.0%)	0 (0.0%)
Strongly Disagree=2	0 (0.0%)	0 (0.0%)	0 (0.0%)
Weakly Disagree=3	0 (0.0%)	0 (0.0%)	0 (0.0%)
Neutral = 4	0 (0.0%)	0 (0.0%)	0 (0.0%)
Weakly Agree=5	1 (8.3%)	0 (0.0%)	1 (4.2%)
Strongly Agree=6	8 (66.7%)	5 (41.7%)	13 (54.2%)
Most Strongly Agree=7	3 (25.0%)	7 (58.3%)	10 (41.7%)
Mean	6.167	6.583	6.375

Std. Dev.	0.577	0.515	0.576

TABLE 24: Respondent Ratings for Statement of Affirmation #4: Relevant Thinking Pathways

The most significant difference in responses was that the academics clustered more tightly on the “strongly agree” option while the practitioners focused on the “most strongly agree” alternative. The one practitioner who scored this response as “weakly agreed” offered no explanation. Perhaps the reason for the slightly lower ratings by the academics might be associated with their propensity to deal with categorization and taxonomies; it is believed that practitioners tend to focus on required actions rather than decomposing the hierarchy of categorical data.

Other respondents commented more favorably, as follows:

- “Very exhaustive as well as selective literature was reviewed and studied deeply.”
- “Complete, very wide, and detailed literature study, with relevant reference to research topic.”
- “Full history of all relevant scientific fields very well described, with clear relevance to topic on hand.”
- “The depth of the literature investigation is impressive.”

Overall, these findings indicate that the cohorts’ scores were relatively consistent despite the minor differences observed. These results are considered to support this statement of affirmation.

7.7 Statement of Affirmation #5: Response Ratings and Commentary—Literature Completeness and Significance

This portion of the survey addressed the completeness and significance of the literature cited in this dissertation and the historical review developed for the grounded research. The responses for this statement had the second lowest score in the survey. One practitioner provided a rating of "weakly disagree" and commented, "Agree with completeness. Disagree with significance. Many things have statistical significance without being important." That comment, however, indicates that the respondent had not made his or her judgement based on the operational definition that had been provided (see Chapter VI).

The survey had instructed respondents to evaluate the completeness of the literature search. Statistical significance was not determined for this item; instead, a judgment was requested regarding the practical significance of the research. The responses for both of the research cohorts were close for the means and standard deviations as indicated in Table 25.

Professional Category	Number of Responses (Percent of Professional Category or Total)		
	Academics	Practitioners	Total
Most Strongly Disagree=1	0 (0.0%)	0 (0.0%)	0 (0.0%)
Strongly Disagree=2	0 (0.0%)	0 (0.0%)	0 (0.0%)
Weakly Disagree=3	0 (0.0%)	1 (8.3%)	1 (4.2%)
Neutral = 4	1 (8.3%)	1 (8.3%)	2 (8.3%)
Weakly Agree=5	1 (8.3%)	0 (0.0%)	1 (4.2%)
Strongly Agree=6	7 (58.3%)	4 (33.3%)	11 (45.8%)
Most Strongly Agree=7	3 (25.0%)	6 (50.0%)	9 (37.5%)
Mean	6	6.083	6.042
Std. Dev.	0.853	1.311	1.083

TABLE 25: Respondent Ratings for Statement of Affirmation #5: Literature Completeness and Significance

7.8 Statement of Affirmation #6: Response Ratings and Commentary—Contribution Significance

This statement assessed the respondents' value perceptions of the proposition delivered in the grounded research theory of profound knowledge, considering its ability to explain the Bayesian moment. Respondents' ratings are reported in Table 26.

Professional Category	Number of Responses (Percent of Professional Category or Total)		
	Academics	Practitioners	Total
Most Strongly Disagree=1	0 (0.0%)	0 (0.0%)	0 (0.0%)
Strongly Disagree=2	0 (0.0%)	0 (0.0%)	0 (0.0%)
Weakly Disagree=3	0 (0.0%)	0 (0.0%)	0 (0.0%)
Neutral = 4	0 (0.0%)	1 (8.3%)	1 (4.2%)
Weakly Agree=5	1 (8.3%)	0 (0.0%)	1 (4.2%)
Strongly Agree=6	7 (58.3%)	8 (66.7%)	15 (62.5%)
Most Strongly Agree=7	4 (33.3%)	3 (25.0%)	7 (29.2%)
Mean	6.25	6.083	6.167
Std. Dev.	0.622	0.793	0.702

TABLE 26: Respondent Ratings for Statement of Affirmation #6: Contribution Significance

This item also had a strong correspondence between the two cohorts in both mean and standard deviation. Those participants who scored the question either "weakly agree" or "neutral" did not offer any comments to explain their perspectives. Nevertheless, the overall results were favorable.

7.9 Statement of Affirmation #7: Response Ratings and Commentary—Advancement of Quality Knowledge

Results for the final statement of affirmation are presented in Table 27.

Professional Category	Number of Responses (Percent of Professional Category or Total)		
	Academics	Practitioners	Total
Most Strongly Disagree=1	0 (0.0%)	0 (0.0%)	0 (0.0%)
Strongly Disagree=2	0 (0.0%)	0 (0.0%)	0 (0.0%)
Weakly Disagree=3	0 (0.0%)	0 (0.0%)	0 (0.0%)
Neutral = 4	0 (0.0%)	0 (0.0%)	0 (0.0%)
Weakly Agree=5	2 (16.7%)	2 (16.7%)	4 (16.7%)
Strongly Agree=6	9 (75.0%)	7 (58.3%)	16 (66.7%)
Most Strongly Agree=7	1 (8.3%)	3 (25.0%)	4 (16.7%)
Mean	5.917	6.083	6.000
Std. Dev.	0.515	0.669	0.590

TABLE 27: Respondent Ratings for Statement of Affirmation #7: Advancement of Quality Knowledge

This was the lowest-rated area in the entire survey. That may have been because it required respondents to employ their most broad and lofty judgments. Two comments describe the challenges associated with responding to this survey item. The first was submitted by a practitioner who had entered a score of "weakly agree," and the second was from an academic who had provided a “strongly agree” rating. Based on their comments it is difficult to understand the rationale of their differing views.

“The theory of profound knowledge with Bayesian moment will give a new conceptual frame and valuable tool to explain the relation of data and information of history, future, and present moment to the decision-making process and especially to the point deciding something. Furthermore, it explains further than anything before why future is not what it should be when right tools and methods are not applied and poor-quality information is used to backup opinion-based decision making.”

“This is more difficult to judge. It makes a definite contribution to the body of quality knowledge and is quite innovative. The promises for the future are more difficult to assess. It is clear that this represents a contribution that advances the evolution of knowledge and opens many possibilities to extend the research. In history this may be judged as one of the most salient advances in the literature about quality; however, it is a little premature to make this judgment very strongly at the present time.”

Given the tight ratings’ agreements for the cohorts’ means and standard deviations, it seems reasonable to presumed that this research is promising in terms of its ability to extend future researchers’ investigations and further expand this body of knowledge.

Indeed, additional research also was recommended by the respondents, including investigation of the idea proposed in the epistemology of Lewis (1929) regarding the origins of knowledge as related to experience and how knowledge changes future experience (pp. 232-233). Additionally, other references were provided that had not been included in this dissertation but could be used to shape future research directions, including Bo Bergman’s (2007) paper on conceptualistic pragmatism (pp. 86-93); John C. Anderson, Kevin J. Dooley, and Susan D. A. Misterek’s paper (1991), “The Role of Profound Knowledge in the Continual Improvement of Quality” (pp. 243-

259); and Deming's unpublished paper dated July 21, 1989, that was titled "Foundation for Management of Quality in the Western World" (Deming, 1989) These proposed additions were received too late to be included in this dissertation, but they will be investigated during the next phase of research.

7.10 Respondent Commentaries

One practitioner did such a thorough job in his or her critique that the responses to several of the survey items are presented below:

> The first of the two research questions that Watson has formulated is complex. He seeks to evolve 'thinking pathways' from Deming's system and from it derive the properties and principles of the Bayesian moment of managerial choice and the categories that define the related knowledge framework. In the second, Watson seeks to enlarge the Deming system into a comprehensive theory that influences organizational transformations. Both these questions are audacious in scope and depth. The most original concept in the dissertation is the Bayesian moment. Deming was intensely concerned with building up the 'degree of belief' through successive tests, and Shewhart had the same concerns. Yet, neither of them, nor for that matter any of their followers, shows the slightest awareness of Bayesian statistics, which with its a priori and conditional probabilities dealt with the subjective (belief) through successive quantifications. The integration of the methods of Bayes with those of Shewhart warrants future research and attention of academics. Watson does not attempt this, at least, not yet. But he sees that at the junction of hindsight and insight lies the Bayesian moment which, either intuitively or formally deals with the degree of conditional belief needed to make a choice. The first research question is thus innovative beyond doubt. The second question arises from a 'sense of incompleteness' about what Deming left us with. One senses

profundity, and yet one wishes there was more to come. The question is whether the propositions of Deming can be expanded into a coherent theory based on historical sources (that Watson has so comprehensively tapped) and the pathways they generate. Can the work of Deming be completed? This too is a bold challenge, and an original one, especially as Deming followers in the past three decades have stuck to the exact words that Deming uttered and have desisted from explorations beyond…

…Watson's historical research is immense and includes philosophers like Aristotle, Bacon, Hume, Clifford, William James, Herbert Spencer, and thinkers like Peirce, Broad, Karl Pearson, Shewhart, Korzybski, Hoffer, Stuart Chase, and many more. He devotes a whole chapter to the evolution of thinking about belief, probability, science, systems, quality, and learning that together arguably provides the greatest collection of historical literature ranging from philosophy to management to bring up the background to Deming's work and to quality in general. The six topics chosen are appropriate for developing the thesis. For each of the six 'evolutions' a logically arranged and argued reference to historic writing has been provided. This represents great erudition. Every reference is relevant to the stream under consideration. For the future, though, it may be useful to classify the philosophers so that the positivists stand out distinct from others. Insights from systems thinkers too might prove distinctive. This may provide fresh insights into the nature of the evolution of these six elements…

…The one thing that stands out throughout the dissertation is the dipping into literature from sources that cover philosophy, psychology, system dynamics, and methods of science, statistics, semantics, and early works on management. Watson draws from American, European, and Japanese literature. It is hard to find useful literature that Watson may have omitted. Apart from footnotes, lists of relevant literature provide validity to the evolution of as many as six thinking pathways (IV). In fact, one of the side-benefits of this dissertation is that it provides a near-complete bibliography for anyone wishing to delve into the historical evolution of management thought. One possible issue that arises out of using such an eclectic mix of background literature is that one may wish for some classification. One way to discriminate would be to separate the positivists from others. Despite his assertion that even a single case can disprove a theory, Deming cannot be called a positivist. His condemnation of performance appraisal (coming from the principles of variation) and his defense of workers as a community are but two illustrations that set him apart. So, one possible avenue for future research would be to separately line up positivist thinkers (including Popper and Kahneman) on the one hand and others (Einstein, William James…) and see how they stack up with Deming's philosophy. In extending the range of background study, one could think of Polanyi, Wilber, Beck, and Cowan, and psychologists like Maslow and Graves. My hypothesis would be that by separating the positivists and including some others, this thesis might stand even more vindicated! But this is really a wish for the future, for I have never seen a more exhaustive investigation of background literature than in this dissertation. In fact, one of the side-benefits of this dissertation is that it provides a near-complete bibliography for anyone wishing to delve into the historical evolution of management thought…

…The premise in this thesis is that Deming but presented a kernel of his thinking–which he might have dwelt on for long years and which might have influenced his 14 points and lists of obstacles and deadly diseases–and therefore an elaboration is a necessity. To do this 'extrapolation' Watson starts with what he calls 'axiomatic' definitions of eleven terms including some which are central to his thesis–like bounded rationality and sense-making–and just touches upon Merton's unintended consequences. Watson then produces the operational definition of profound knowledge, something he was leading up to all this while, and in sharp distinction, defines profane knowledge which is characterized by superficiality and lack of objective data analysis, as it proceeds from intuition and subjective judgment of reality. These are not intended to be open ended definitions but are made in the context of organizational performance and transformation. The dismissal of intuition must be viewed in this context and not as its negation in situations calling for creativity and innovation. The distinction becomes clearer in the table which characterizes profound knowledge with the tacit and latent functionality and the profane with the explicit and manifest functionality. The distinction comes across as 'good' and 'bad'–terms that come up in the proposed definition of quality in terms of goodness and badness. The assertion is made that the expanded theory addresses the 'unknown unknowns' in searching for common causes so that an organization may be helped to transform itself. The elements of profound knowledge are elaborated: 'understanding a system' for instance becomes integration of system architecture, and so on. The theoretical and 'practical' aspects of profound knowledge are compared as are the requirements for learning. Here the double-loop learning model of Argyris is expanded into a triple-loop model linked to PDCA cycle (rather than the PDSA), which then becomes the heart of the Bayesian moment. Three principles emerge, dealing with leadership and system, statistical methods for stability and change, and employee engagement with collaboration. Profound knowledge is associated with mindfulness. Predictions are rational in the sense of being grounded on facts, and yet there is the question of degree of belief attached to these facts. The dissertation thus confirms Deming's theory of profound knowledge through a comprehensive and widely scoped study of literature. At the same time, it fulfills the initial promise of expanding on it. The concept of Bayesian moment is the most significant aspect of this elaboration. It provides a model for a learning journey and puts in perspective the step of sorting through profane knowledge, as in exploratory data analysis. It puts the PDCA cycle in the Bayesian moment, thus incorporating it into the overall model. It links hindsight and foresight through insight, using a scientific approach. And finally, it provides clear indications for future research, as it promised…

…Clearly Watson is aiming at the executive level. He aims at 'strategic change' and that includes restructuring an organization's purpose; and 'transformational decisions' based on profound knowledge. True to the Deming way, Watson integrates the scientific method at the executive level with a collaborative approach. The dissertation builds a workable structure of thinking and practice at the level of strategy management. The triple loop of learning is connected to strategic management to address the question of how we know that what we are doing is right (This expands on Deming's 'study' step). The dissertation weaves into its structure both systems thinking and strategic thinking– the latter is connected to the essential process of prediction at the Bayesian moment, dealing with the issue, 'How do we keep the business going?,' posed by Deming. The thesis combines engagement with statistical methods–for effective execution. Thus, while the main contribution of the dissertation is at the level of thought, it maintains a close connection to what is to be done, especially by top management. The concepts here can well become part of the standard literature used to teach and disseminate management focused on quality (by whatever name called) all over the world. Opinions about the proposed future research: The dissertation proposes work on transformational decision-making process at the executive level and clarifying meaning. It proposes 'rigorous inquiry into the scientific basis of decision making' to help improve the quality of choice. It also calls for work on the related 'behavioral dynamics' and on producing 'enhanced methods' for the pursuit of profound knowledge in strategy formulation. The thesis is so structured as to enable expanded work in the future. Post-dissertation work may also involve practical applications and the incorporation of the theory into teaching and training literature. These are proposals that can lead many scholars into this field. In addition to what is proposed, I think there may be scope for research into combining the principles and methods of Bayesian statistics with those of Shewhart charts to build a wholesome model of prediction in a variety of situations. In summary, arising out of this dissertation, there is great scope for multiple research projects.

CHAPTER VIII

CONCLUSIONS OF THE RESEARCH: ESTABLISHING THE THEORY OF PROFOUND KNOWLEDGE

8.1 Conclusions Regarding the Theory of Profound Knowledge

This research has developed a new framework for defining profound Knowledge and applying it within the context of organizational decision making. That theory pays particular attention to strategic choices related to improvement of quality. This theory of profound knowledge emerged from a grounded research study of literature originally proposed by Shewhart as recommended in his book, *The Economic Control of Quality of Manufactured Product.* His protégé, Deming, then proposed a system of profound knowledge in his 1992 book, *The New Economics* based on four elements. The new theory of profound knowledge expands on Deming's framework and provides a scientifically based approach for conducting operationally oriented inquiries into organizational performance assessment. It is can be used as the basis for establishment of transformational projects and applied to create objectively based proposals for change.

8.2 Conclusions Regarding the Mental Model of the Bayesian Moment

Profound knowledge is developed within the Bayesian moment that exists when hindsight is evaluated with insight to create foresight–a predictive approach for defining how future states of organizational performance will behave based on a comprehensive understanding of the historical and current states of the organization's operations. The Bayesian moment reflects a deep appreciation of philosophy, reaching back to the Greek civilization, that were accepted more generated following the blossoming of scientific thinking in the 20th century after Albert Einstein's postulation of the theories of special and general relativity, which reinvented the approach to scientific discovery when uncertainty and the inability to directly test scientific propositions exist. The Bayesian moment mental model incorporates the elements of the theory of profound knowledge, and the activity associated with the Bayesian moment actually involves a derivation of the Shewhart Cycle, which has been a core element in modern quality thinking since the mid-1950s.The critical component of the Bayesian moment is the opportunity for executives to formulate alternatives and choose future directions and strategic plans for projects that will transform their organizations from the current to the desired future state.

8.3 Conclusions Regarding the Application of the Theory of Profound Knowledge to EDM

Although the subject of EDM is expected to be conducted in the future, this current research has, nevertheless, provided a strong foundation for those future inquiries. In fact, EDM embraces many of the core elements present in the theory of profound knowledge. These elements help establish the integrity of information on which decisions are made and develop reflective insights into opportunities for experimenting with decision pathways that lead to the achievement of desired future states. The hypothesis for future research might be that executives must manage resource flows of their organizations by applying the theory of profound knowledge to direct investments to those areas in the work environment that most need improvement in order to increase the capacity and capability of the entire work system.

Chapter IX discusses future research opportunities in much the same way that Shewhart made his proposals. However, in this case, the proposed research incorporates the mental models that emerged from this current investigation.

CHAPTER IX

RECOMMENDATIONS FOR FUTURE GROUNDED RESEARCH: INVESTIGATION RELATED TO THE THEORY OF PROFOUND KNOWLEDGE

Because this dissertation research began with an assessment of Shewhart's (1931) recommendations for research in the appendix to his book, it is appropriate that future opportunities for conducting those studies be described. When this dissertation was initiated, its emphasis was on EDM. However, as the dissertation research progressed, several mental models related to organizational transformation within the Bayesian moment mental model surfaced, illuminating the subject of EDM. This chapter provides a brief description of five new directions for potential follow-up studies.

Many mental models that have been proposed in the past arose out of what may be called serendipitous discoveries based on subjective insights that were not grounded in scientific inquiry. Instead, they have been promoted dogmatically by proponents of a particular school of thinking. However, true purposeful scientific inquiry is required to develop reliable advances in knowledge.

Indeed, if an organization aspires to operate, as Ackoff (1971) described, as "a system of systems" (p. 662), then all of its components must be designed with their interactions in mind, not just the desired performance criteria of their individual system components. Emphasis related to future organizational design needs to focus on factors of interoperability, cross-functionality, portability, extendibility, reuse, and commonality, as software development methods require. Rapidly growing organizations need to consider how they can operate according to the principles of object-oriented programming and develop future capability by reusing validated and verified legacy systems that previously have been optimized. This approach generates reliable future applications that effectively and efficiently address emerging technological advancements.

According to Deming, the key component of the future design of organizations for improved operability evolves out of a statistical understanding of performance. Deming also commented on how he had approached the practice of statistics.

> I aim to engage only in work that offers opportunity to create new statistical methods, or to use existing methods to help other scientists and professional men to improve their research; or to acquire new knowledge through planned research about materials and about man; or to improve efficiency, uniformity, quality service, and performance of product; or to achieve smoother operation and more effective administration and management in industry and government (ASA, n.d.).

The common objective of the proposed research directions is to demonstrate the interactions that occur when different considerations are combined to create a holistic perspective regarding strategic change initiatives. This chapter endorses Deming's approach to continually pursuing new knowledge and the researcher's observation that profound knowledge does not arise out of totally empirical, positivist analytics but has a human component associated with the design of organizations that is essential for understanding how organizational systems operate. This insight applies a sociological perspective to the Bayesian moment and a concern regarding how human activities are organized in order to create profound knowledge, which was described by Herbert

G. Blumer (1969) who lived from 1900 to 1987, as “symbolic interactionalism to the study of human group life and human conduct” (p. 1). In the next section, his theory will be described and related to the study of human interactions and learning how work processes are interpreted and actions developed in order to apply profound knowledge to improve organizational transformation and achieve targeted performance objectives. Additionally, the mental models that emerged from the current research will be presented to support the five proposed research inquiries. Finally, a summary of the way those models relate to EDM will be discussed.

9.1 Symbolic Interaction Related to the Profound Knowledge of Organizations

What is symbolic interaction and how does it relate to the Bayesian moment mental model? The Bayesian moment indicates a continuing, ongoing emergence of an organization’s reality and developing insight into the evolving meaning that is required in order to draw conclusions or make decisions. This continual redefinition of the understanding of reality by the decision makers in the Bayesian moment constitutes a social activity, associated with a symbolic interaction. According to Blumer (1969), developing insight is a social activity that involves interpreting objects to gain meaning that requires action (pp. 20-21). People “live in a world of objects and are guided in their orientation and action by the meaning of these objects” (Blumer, 1969, p. 21). An object is “anything that can be referred to” (Blumer, 1969, p. 68). Most importantly, objects are “human constructs” (Blumer, 1969, p. 68). Blumer’s (1969) concept of objects identifies three different types: physical, social, and abstract. Physical objects are essentially the same concept as Whitehead’s “actual entity” (Whitehead, 1985, pp. 41, 199-206); however, Blumer (1969) expands the concept to include human social relationships and abstract human constructs (e.g., mental and moral models of meaning) (p. 21). These objects are “formed, sustained, weakened and transformed in their interaction with one another” (Blumer, 1969, p. 21). Systems do not function because of their requirements; they function because people have designed them to interact in certain ways and define the circumstances within which they are caused to act. A collection of associated objects comprise a social process which is created by the nature of the interaction that is gained through the communication of meaning. Humans act based on meaning that they derive from their network of influencing communicative objects. This meaning is communicated through the symbols that represent the system of objects, and it is a social product that is not inherent in the objects themselves but which represents the represents the people's understanding of the various "gestures" of the system's significant symbols through a continuous process of action and interaction (Blumer, 1969, pp. 6-21).

Symbolic interactionalism can be summarized in Blumer's (1969) words as follows:

> The term "symbolic interaction" refers, of course, to the peculiar and distinctive character of interaction as it takes place between human beings. The peculiarity consists in the fact that human beings interpret or "define" each other's actions instead of merely reacting to each other's actions. Their "response" is not made directly to the actions of one another but instead is based on the meaning which they attach to such actions. Thus, human interaction is mediated by the use of symbols, by interpretation, or by ascertaining the meaning of one another's actions. This mediation is equivalent to inserting a process of interpretation between stimulus and response in the case of human behavior" (pp. 6-21).

Shewhart (1939) described semiotic meaning, which studies communicative behavior using signs and symbols to describe meaningful behavior, and he defined a positivist approach to scientific prediction that requires empirically deduced meanings (p. 123). However, human systems do not simply operate on empiricism as recognized in the precepts of the theory of profound knowledge defined in Chapter V. Chase (1938) observed that problems in meaning come from lack of clarity among objects and referents (p. 63). Ogden and Richards (1923) noted that symbols are used to make reflective references to intangible circumstances so that implicit abstractions about performance of processes may become concrete enough to permit their communication (p. 11). To crystallize knowledge and share it organizationally and thereby effect change, it is essential that communications be clear and interpretable across the organization’s processes and within the organization’s functions. In this way, messages transmitted to the organization can specify desired actions which the system is capable of performing in a coordinated manner that makes the most effective and efficient use of resources for stimulating change and reporting the outcomes of the system change, satisfying the originally perceived need for strategic change. These transactions require integrated operation of a variety of mental models in the social actions of the organization because no other single model has been discovered to integrate all aspects of this problem in a comprehensive way.

During the research phase associated with this dissertation, five mental models were developed to define the operational framework of the Bayesian moment for EDM. Each of these models treats Blumer’s object in a different way, but they collectively enable the development of decision alternatives for executives. These models are introduced sequentially in the following sub-sections, and then they are combined to provide a system of systems mental model of the operations within the Bayesian moment, leading to executive decisions for the identification of options that can transform organizations. An extended inquiry into the nature and operation of these models is required because the treatment in this chapter only introduces the point from which additional research into this subject can be leveraged.

9.1.1 Mental Model #1: Structural Hierarchy of Organizational Gemba

The focus of this mental model is on characterization of workplace dynamic for the communication of meaning.

9.1.2 Mental Model #2: Hierarchical Structure of Kanri for Formulation and Deployment of Strategy

This mental model defines the planning and execution infrastructure for identifying strategic change projects that will have a recognized potential for transforming the organization.

9.1.3 Mental Model #3: Coordinated Approach to Structured Continual Improvement Projects

This mental model addresses improvement projects and integrating them into standard ways of working.

9.1.4 Mental Model #4: Collaborative Analytics and Identification of Meaningful Relationships

The method for identifying interrelationships among data that have the potential to convey essential meaning tor EDM is represented by this mental model.

9.1.5 Mental Model #5: Statistical Storytelling for Pursuit of Causal Relationships

This mental model explains the method for determining the causal nature existing among the interrelationships of work processes. These relationships generate the ability to exercise higher levels of control (according to the Shewhart's theory of control) and increase a higher prediction probability regarding the potential future states.

9.1.6 Integration of the Mental Models Associated With the Operation of the Bayesian Model

These five mental models operate synergistically, so they generate circumstances in which executives can formulate management decisions under the conditions of bounded rationality that were proposed by Simon (1997, pp. 118-122). Thus future research not only needs to validate and verify each of them independently but also to evaluate them as a coherent system. That investigation needs to prove that the integrated system operates collectively to support the EDM capability and does so by providing meaning that is both actionable and able to achieve the targeted transformative state of the organization's strategic intent. As statistician George E. P. Box (1919-2013) succinctly described the merit of mental models, "All models are wrong, but some models are useful" (Box, Hunter, & Hunter, pp. 208, 384, 440). Examining this system of systems and its supporting EDM processes can inform business leaders and help them to improve the quality of their future decisions.

9.2 Bifurcation of Organizations Into Distinct Gemba

Recently the Japanese word, "gemba (現場)," has been used liberally by Western management consultants to refer to the shop floor of a production organization, where value is produced and waste and losses are accumulated. However, the etymology of this word and its actual usage collectively infer a much deeper meaning.

Whenever a Japanese kanji (漢字) term is used, people often assume that the word reflects an ancient meaning that can be described through a story. These Chinese characters were borrowed by Japan around the fifth century to create a written language and kanji words operate more like pictograms than letters. So they communicate graphically, offering a rich collection of ideas that unite into a transferrable meaning. Other Japanese terms are written in hiragana (平仮名) and *katakana* (片仮名) characters, which are part of a phonetic lettering system that describe the sounds of syllables that compose a word. Many of these words have been converted into romaji, (ローマ字) which is based on the Latin alphabet. Thus, it is important to understand the story behind the pictographs whenever a word is written in kanji characters because there may be more to its meaning than a simple translation can express. This is definitely true of the word gemba.

The kanji version of the word gemba combines four Chinese characters that provide an etymological story, describing its meaning. At sunset, the king surveys his kingdom, and observes a pigsty! This can be restated as the leader observes his domain of control at the end of a regular work period and notices reality. The gemba is a place of reality. It is a place where value can be created or destroyed. It is the place where problems are visible and improvement ideas also can be generated naturally. A more comprehensive explanation of gemba can be derived by using the who, what, where, when, why, and how (5W+1H) method of asking questions about a process or problem being defined in conjunction with an improvement project (see Figure 23). Using this structured breakdown clarifies the meaning of the word gemba. Gemba not only describes the place where an organization's working class toils, but it also summarizes an action or process that for which the executive function is responsible. In fact, it can be surmised that going to the gemba that is an essential aspect of decision-making authority. What is this executive action? What is this accountability for exercising decision rights? How should this responsibility be performed? What should the executive be observing when he or she goes to the gemba to determine if an opportunity for continual improvement exists? These questions will be addressed in the next section of this dissertation.

5W + 1 H QUESTIONS:		ANSWERS:
What happened?	→	Survey – conduct a detailed scrutiny
Who was there?	→	The King – executive function
When did it happen?	→	At Sunset – end of working period
Where did it happen?	→	At the point of doing the real work
Why did it happen?	→	To understand the real thing
How did it happen?	→	Personal activity required to notice

FIGURE 23: A 5W+1H Description of the Gemba

9.2.1 How to Interpret Gemba From an Executive Perspective

The concept of gemba encourages leaders to investigate personally and see more clearly how to improve the resource effectiveness, efficiency, and economics of their organizations by focusing on the work that is done at the front line where value is produced. This requires leaders to develop situational awareness in order to observe the true current state of their organizations' work environments and to increase their sense-making capabilities. This makes it possible for leaders to understand what they notice in those observations. In this way leaders can understand the real issues that exist in their workplaces and provide proper assistance for streamlining work flows and eliminating the waste that exists while meeting customer needs. According to social psychologist Weick (1979; 1995), situational awareness and sense-making are essential skills for leaders who are guiding and directing transformation in the way that work is accomplished by coupling control with authority and developing "explanatory possibilities" (p. 17; pp. 2-5). Most importantly, this description of gemba emphasizes that this activity is a routine action and expectation of the executive function in organizations. These skills make it possible for leaders to cast off over-reliance on summary data and filtered information that distorts the observations of the gemba, which migrate to them through the process of upward reporting. These leaders also gain what can be called profound knowledge regarding the way that processes actually work in their organizations. The unique value of an engaged executive in the gemba emerges from his or her ability to apply resources to effect the improvement of operational work flows which is a responsibility that exceeds the front-line workers' responsibilities. In this way, an executive can cut through the dirty data that describes the messy process and obtain enlightenment about what must be changed to improve results.

9.2.2 Discerning Distinctions Between the Two Gemba

This section title implies that the reality of the gemba operates in a way that reflects two distinct situations. The first involves the workplace, and it is a tangible gemba that delivers value to customers through the productive work output of the organization's process activities in an operational sense. The second is associated with the executive function, and it represents an intangible gemba that delivers monetary value to shareholders through the way that effective, efficient, and economic processes create value from work.

Gemba 1 manages the physical work that is performed by an organization; it is the gemba of action. Gemba 2 manages the reflective work of the organization–the planning and organizing of conduct and improvement in the physical workplace. This is the gemba of thought where action is planned and opportunities for improvement are identified and resourced.

In fact, most organizations possess both types of gemba, which focus on two distinctly different customers. Gemba 1 is where the actual entity (whether a product or a service) produced by an organization is designed and delivered to the external consuming customer in fulfillment of a proffered value proposition for the marketplace. Gemba 2 is where plans for the execution and improvement of Gemba 1 are conceived and outcomes are delivered as indicated by return on resource investments by commercial customers who are financial investors and government tax authorities.

This division of organizational perspectives creates a two-sided way of observing the actual work conducted by an organization. The Gemba 2 perspective is top-down, viewed through the lens of an external financial perspective and translated into a monetary language. On the other hand, the Gemba 1 perspective is initiated at the bottom of the organization and moves upward, starting with the actual work performed to produce the value offered as a product or service, which is viewed through the physical lens of human activity (see Figure 24).

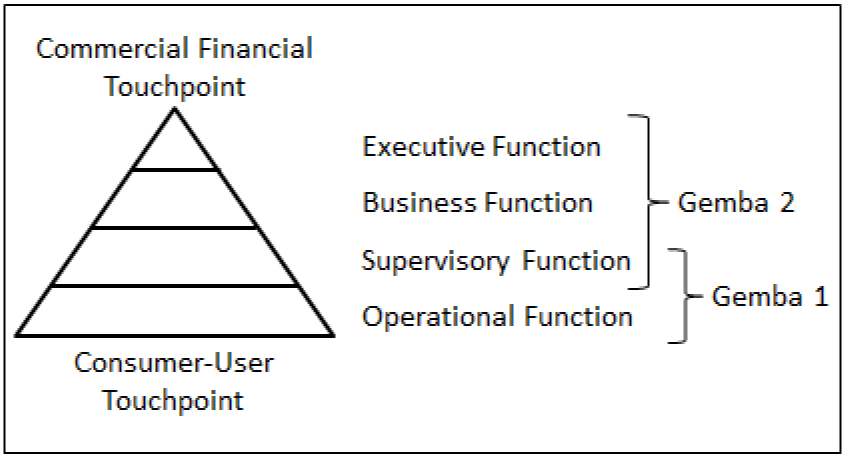

FIGURE 24: The Two-Sided Gemba of Organizations

Perhaps it is easier to notice and understand Gemba 1 when it is described in terms of physical activity and work that is perceived as movement and action. This tangible gemba is salient because it can be touched, examined, and improved by direct reflection on the way that the associated work processes operate. This gemba represents a world of reality, examining the actual produced entity.

This approach to examining work performance is epitomized in the Japanese exhortation, genichi gembutsu (現地現物)—physically go and see! This phrase embeds the five real observations that are the focus of discovery. The Japanese word for real actually is the first syllable of gemba. Tracing its applied meaning provides a deeper understanding of why "gen" is a very appropriate word choice for the circumstances being described in this discussion of Gemba 1. It is necessary to understand the five real observations in order to gain insights to reveal problems by; going to the real place [gemba (現場)] to observe the real thing [gembutsu (現物)]. This action leads to discovery of the real facts [genjitsu (現術)] and referring to the real reason (or theory) that described what really is happening [genri (原理)]. Then, standards (or rules) that are based on proven good practices need to be followed in order to implement countermeasures that will return the process back to its state of real control [gensoku (原則)]. This description of Gemba 1 is relatively straight-forward; however, the abstractness identified with Gemba 2 is more difficult to understand.

9.2.3 Comparing and Contrasting Gemba 1 and Gemba 2

Alignment of this two-sided view of organizations requires rationalization of the Western view that uses Cartesian logic by identifying natural dualisms as representing in two distinctly opposing states of mental and physical activities, juxtapositions them as two extreme alternatives (e.g., things were either good or bad; actions were either good or evil). When using this perspective, compromising and establishing a middle ground for this mental model would not be an acceptable neutral state between two extremes. However, if these two limiting dimensions have not been defined operationally into rational sub-groups, then there can be many subjective distinctions for understanding their alternative worlds—and those alternatives might not be readily apparent without deeply insightful consideration. What constitutes a clear, concise, and comprehensive delineation between activities comprising Gemba 1 and Gemba 2?

In his book, *Thinking, Fast and Slow*, Kahneman (2011) identified two systems of thinking that describe how people make decisions. He described them as System 1, emotionally based or fast thinking, and System 2, rationally based or slow thinking, and they relate directly to the division between Gemba 1 and Gemba 2. Kahneman observed that about 70 percent of executive decisions rely on System 1 thinking and predominantly use emotionally based choices. A state of willful ignorance can be generated when management pursues sense-making only passively based on superficial situational awareness and then bases all decisions on System 1 criteria. Willful ignorance is fueled by over reliance on Kahneman's continuously operating, emotionally driven System 1 thinking and is unfettered by any constraints derived from System 2's logically deduced rules that can provide a steering function that establishes operating boundaries for System 1 thinking. “The success of System 1 is the coherence of the story it manages to create” (Kahneman, 2011, p. 85).

Although operation of these two thinking systems is not constrained structurally, it is interesting to observe that System 2 thinking dominates Gemba 1 while System 1 thinking dominates Gemba 2. The condition of willful ignorance may lead to executive excusing when predicted potential or future states fail to materialize and what formerly may have been considered to be a coherent story about strategy and a solid set of decision criteria that stimulated the original choice, reduces to incoherence. Thus taking a pathway that results in willful ignorance is an indicator of a lack of executive responsibility for managing by facts.

In their book, *This is Lean: Resolving the Efficiency Paradox*, professors Niklas Modig (1977-) and Pär Åhlström (1965-) (Modig & Åhlström, 2012) identified two flows that need to be managed in organizations to achieve efficiency, flow efficiency and resource efficiency. The process owner for flow efficiency management is responsible for the tangible gemba where physical work is managed to produce goods and provide services (Modig & Åhlström, 2012, p. 7). However, leaders are the process owners for Gemba 2, where resources are allocated and activities are connected to the ownership of the organization and its financial performance and therefore must manage the flow of the organizations resource efficiency.

Interestingly, these two gemba are quite distinct. The contrast in the ways they think, talk, and work is very apparent, and it can be characterized using descriptions of their dominant quality characteristics (see Table 28).

Quality Characteristic	Gemba 1	Gemba 2
Dominant Entity Type	Tangible Work	Intangible Work
Measurement Type	Physical (Time)	Financial (Money)

Management Objective for Performance	Productivity Growth– Unit Volume Delivered	Economic Growth– Profitability
Efficiency Leverage	Flow Efficiency	Resource Efficiency
Quality Emphasis	Product Quality	Financial Quality
Leadership Initiative	Worker Decisions	Manager Decisions
Constructive Focus	Internalities	Externalities
Dominant Thinking Style	System 2 Thinking	System 1 Thinking
Improvement Emphasis	Continual/Incremental	Breakthrough/Change
Desired State	Stability/Regularity	Flexibility/Adaptability
Dominant Work Style	Operational Function	Executive Function
Dominant Learning Mode	Kinesthetic/Oral	Oral/Written
Communication Style	Informal/Conversational	Formal/Commanding
Communication Details	Crisply Specific	Abstractly Vague

TABLE 28: Quality Characteristics of the Two Gemba

Research into the roles and responsibilities of the executive function as it applies to these two Gemba is an important precursor to understanding how strategic thinking can be transitioned into operational activities that transform the organization and how communications and instructions are given and received based on the authoritarian structure. These gemba are logically unique, and failure to appreciate their differences creates potential confusion and conflict within an organization. Communication across these gemba is essential for any organization that desires to achieve a successful, collaborative transformation.

9.3 Transformation of Organizations Through Strategic Change Projects

9.3.1 Describing the Japanese System as a "Kanri of Kanri"

Organizational transformation occurs when projects that shift process performance or increase the capability of those processes though incorporation of innovative sub-systems is initiated. Such systemic change requires an end-to-end perspective of the flow of work and resources across the entire system. Although the mental model of the gemba hierarchy provides a linguistic structure for communication across all levels of the organization, a system of kanri defines the way that communications about projects operate within that organizational hierarchy. Each organizational level communicates about its transformation projects, and these communications are embedded within the system called hoshin kanri. The levels of kanri that define the core architecture of a Japanese management system are shown in Table 29.

Japanese Term	Translation
Hinshitsu Kanri (品質管理)	Quality Control
Zenshateki Hinshitsu Kanri (全社的品質管理)	Company-wide Quality Control
Sogoteki Hinshitsu Kanri (前品質管理)	Total Quality Control
Hoshin Kanri (方針管理)	Managing by Policy, Continual Improvement (Breakthrough)
Kinobetsu Kanri (算吧啦管理)	Cross–functional Management System
Kaizen Kanri (改善管理)	Continuous Improvement
Nichijo Kanri (日常管理)	Daily Management System

Jishu Kanri (自首管理)	Self-Management System (Autonomous Management, Self-Control)

TABLE 29: Translation of Japanese Terms That Include “Kanri”

The method of hoshin kanri has been poorly described in Western academic literature and further research is necessary to understand the linkages and interactions among the various kanri that define the activities pursued across and within organizational layers. However, it is also important to understand the impact of what Deming (1986) called constancy of purpose and stated as an organizational imperative, “Create constancy of purpose for improvement of products and services” as the first of his “14 points” (p. 24) for management which, he introduced in his book *Out of the Crisis*. The relentless pursuit of improvement in transforming organizations to achieve strategic intentions through a strategy that has been formulated by management is a critical responsibility of leadership. Achieving this occurs through the effective execution of EDM activities. However, maintaining a continual improvement requires development of an improvement culture. Should that be a culture of continuous improvement or continual improvement? Deming (1986) stated,

> …quality starts with intent, which is fixed by management. The intent must be translated into plans, specifications, tests, in an attempt to deliver to the customer the quality intended, all of which are management’s responsibility. Downstream there will be continual reduction of waste and continual improvement of quality in every activity (p. 49).

Deming had a clear preference for using the phrase continual improvement over continuous improvement, but what difference is there in this seemingly minute linguistic distinction? Does the etymology of these two terms offer any noteworthy differences? Notice that in Table 29 both the terms continual and continuous improvement are used to define different types of kanri in the

Japanese system. Why was this distinction made when that table was prepared?

9.3.2 Distinguishing Between Continuous and Continual Improvement

A discussion of the etymological origins of the words continuous and continual may provide value for differentiating them and determining how they should be applied to organizational cultures and their improvement strategies. In many languages, there is only one word that is used to describe the concept of either of these two terms. For instance, in the Finnish language, the word is "jatkuva;" in German it is "kontinuierliche;" and in Norwegian, "kontinuerlig."

On the other hand, two different terms are used in Japanese. Kaizen generally has been translated to mean continuous, but the Japanese term keizoku tekidesu actually might be better because it implies that an activity is ongoing. So, why did the Japanese choose to use kaizen kanri to describe continuous improvement? Is the distinction between continuous and continual really important?

Strictly speaking, continuous improvement would be an activity that was unceasing or that occurs without interruption. Activities of that type never stop, pause, or hesitate unless a crisis or notable interruption happens. Activities that occur intermittently—even if frequently—are referred to as being continual. This means that pauses occur between their active periods or recurrences. If an activity happens on a regular basis but has discontinuous periods, then it would be continual.

Why is this distinction important in regard to improvement activities? Research into the origins of these words, which are derived from the Latin word, "continuus," and the 12th century French word, "continuel," both mean "joining, connecting with something; following one after another." Then, 14th century French changed the term to "continuell," which means "proceeding without interruption or cessation, often repeated, or very frequent" (Continual, n.d.). These activities recur regularly with short intervals, but they never come to an end.

Conversely, the term “continuous” is derived from a more modern French word, which appeared in literature circa 1635 to 1645. It comes from the same Latin root, but the word, “continueus”’ or “continēre” means an uninterrupted activity (Continuous, n.d.). Given that the two words differ based on whether the associated activity is perpetual or intermittent, determining which one should be used in regard to improvement activities needs to consider how organizations generally conduct improvement projects (Continuous, n.d.).

Although continuous improvement might seem better at first glance, mindless activity can occur continuously without generating improvement. Continual activity that incorporates periods of evaluation and reflection, however, actually may lead to better improvement results.

In fact, kaizen activities that follow either the Japanese PDCA Control Cycle for change management or the standardize-do-check-act cycle for the daily management system and both include the check step, which represents an interruption that askes the reflective questions, “Can this be done better?” and “Can this activity produce a better result?” This check step is reminiscent of the concept proposed by Donald A. Schön (1983) in his book, *The Reflective Practitioner* (pp. 8-9), which advanced the idea of reflective thinking that originally had been proposed by Dewey (1910) in his book, *How We Think*. So when viewed from the perspective of adding value, a planned reflective period can be incredibly valuable. Thus the work process in Gemba 1 should be continuous–steadily producing valuable output for an organization, but, the process of improvement that process gains substantially from the practice of reflection that seeks to find the best way forward over the longer term. In other words, continuous improvement may refer to the incremental gains that workers produce through making work processes proceed better, but continual improvement should be used for project-based improvement, which is the most common approach.

Figure 25 depicts a structure of a Japanese-style system of kanri for strategic management using more Western terms to clarify its communication.

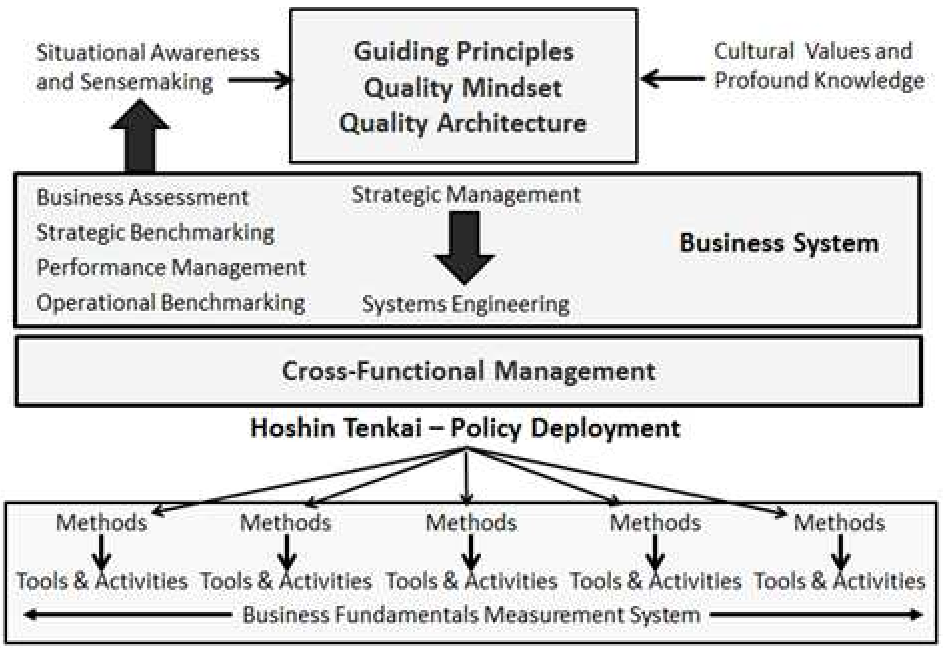

FIGURE 25: A System of Kanri in Japanese-Style Management

Michael E. Porter (1996), who was born in 1947, wrote an article for the *Harvard Business Review* that criticized the Japanese for lack of strategic thinking and planning. He proclaimed that in his view, “Japanese companies need to learn strategy” (Porter, 1996, p. 63). Porter limited his definition of strategy so it did not include improving operational effectiveness but focused on strategic positioning within an industry. However, when considering the military meaning of strategy, there are very different ideas—particularly that grand strategy provides the political relationships and resources required for the engagement; operational art positions the resources that are available to plan an engagement; while tactics position the resources to achieve an operational objective. From this perspective, Japanese management does practice strategy. Perhaps its method of hoshin kanri and its system of kanri provide some lessons that Western managers need to learn!

Figure 26 transforms Japan's hoshin kanri process into one for strategy management. The terms used to describe this process are Westernized; however, the activities that they define exist in both Japanese and Western planning traditions. The process exists at two levels: an executive level for strategy development and deployment (as an executive function that occurs in Gemba 2) and an operational level for implementation and review (as an operational function that occurs in Gemba 1).

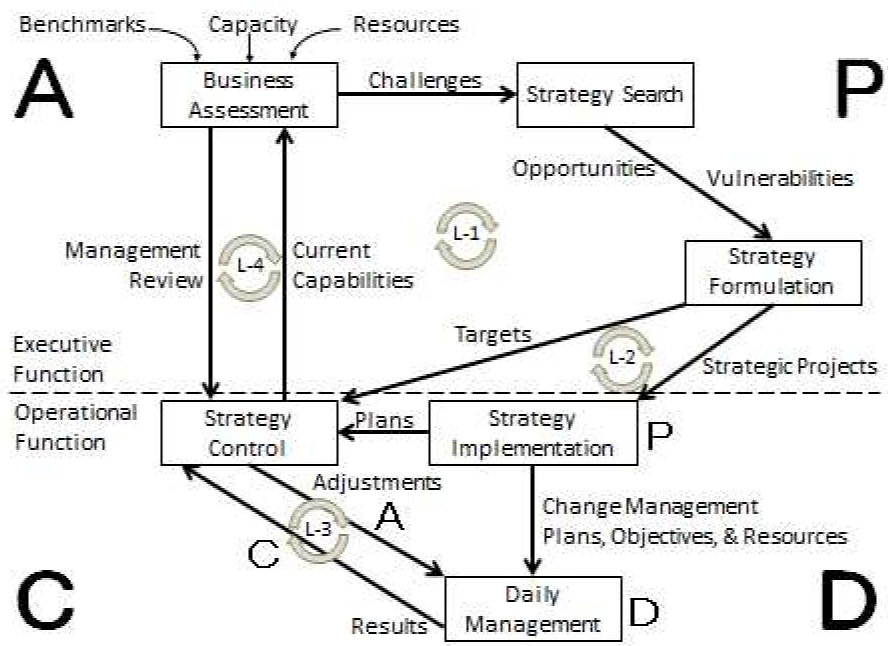

FIGURE 26: Strategy Management Process in the Bayesian Moment

This model consists of four loops–an outer PDCA loop that provides the overall way of planning and executing (L-1) that is supported by three inner PDCA loops for execution and management of the process (L-2, L-3, and L-4). The activities of Gemba 1 represent the roll-out, deployment, or implementation of the strategy, called hoshin tenkai in Japanese). This activity occurs in the workplace and is conducted by the workers. It is a project-focused activity that increases the capability and/or capacity of productive work one project at a time. The activity in Gemba 2 involves business assessment, strategy search, and strategy formulation, where strategic change projects are designed to improve the organization. The EDM function in this activity is to choose the future path that should be funded to achieve the intent of the strategy. This focus on EDM is an area of investigation that requires a deeper understanding of the distinctions between the functions of operations and executives as the principal operational layers in an organization. A summary of the distinctive characteristics augments the differences that were presented previously, as shown in Table 30 (Watson & DeYong, 2018) below.

Characteristics	Operational Function–Gemba 1	Executive Function–Gemba 2
Value Proposition	Appreciated by Customers	Appreciated by Investors
Improvement Effort	Task-related activities	Supervisory activities
Primary Measures	Time, Defects, Cost	Productivity, Financial
Planning Horizon	Daily, Weekly, Monthly	Quarterly, Annually
Dominant Entity	Tangible - Concrete	Intangible–Abstract
Improvement Approach	Continuous Improvement	Continual Improvement
Method Transparency	Visible to Third Party	Invisible to Third Party
Inquiry Approach	Rational-empirical	Rational-phenomenological
Constructive Focus	Internalities of Process	Externalities in Market
Solution Approach	Factual Inquiry	Policy Advocacy
Quality Concept	Quality Strategy	Quality as Strategy
Causal Emphasis	Special Cause	Common Cause
Principal Focus	Control	Breakthrough
Process Emphasis	Do–Act	Plan–Check

Dominant Waste	Muda–Mura	Muri–Mura
Decision Initiative	Worker Decisions	Manager Decisions
Learning Mode	Kinesthetic and Oral	Oral and Written

TABLE 30: Characteristics of Organizational Operating Layers

The two layers of the model describe the processes to be executed by the executive and the operational functions that represent distinct gemba with different work characteristics. These layers possess different languages, data and information characteristics, degrees of dealing with reality, work planning horizons, etc. In fact, they are so different that it is challenging to communicate information about important matters of joint concern easily.

The work conducted by the executive function differs considerably from the work that is accomplished by the operational function. The operational function fulfills a value proposition that is established as the purpose of the organization by the executive function. Each function reports to its own constituency using its own language and measurement system; however, they use two different mechanisms for reporting. The operational function executes the quality strategy and conducts continual improvement of work processes while stabilizing productive output. In the executive function quality is a strategic approach to differentiation and business leaders pursue breakthrough improvements that reinvent the organization and transform it to a performance level that is suitable for future expectations (Watson & DeYong, 2018). People tend to operate with common sense unless they are given a reason to do otherwise. Charlie D. Broad (1914), who lived from 1887 to 1971, observed: “Common sense is naively realistic whenever it does not think that there is some positive reason why it should cease to be so” (p. xii).

The processes that these two layers use to conduct their activities are integrated into a single system flow to combine common sense with the uncommon sense of scientific inquiry in the model of strategy management. The executive function has primary responsibilities for the first three processes while the operational function has the primary responsibility for the second three processes. Both share in responsibility for effective, efficient handoffs between the two layers. The approach to EDM may be classified either as advocacy or inquiry according to Harvard Professors David A. Garvin (1952-2017) and Michael A. Roberto (1969-) (Garvin & Roberto, 2001, pp. 108-116). Advocacy is a process that supports decisions based on special interests or common sense positions and acts to persuade and convince the organization that adherence to the common direction is in the best interest of the organization (Garvin & Roberto, 2001, pp. 108-116). Although inquiry defines the logical, step-by-step approach of the scientific method as applied in operations, the question is: how can such an inquiry be applied in the EDM processes of the executive function instead of over-relying on advocacy as the dominant style? What actually happens in these six processes? Further research into this way of doing strategy can aid in improving the ability of executives to perform EDM.

9.4 Structured Methods as the Approach to Change

Since 2014 IAQ has investigated issues related to decision models used for continual improvement by various functional disciplines to improve performance results. This research program began at the request of the European Organization for Quality (EOQ) to develop a standard approach to the process for conducting Lean Six Sigma improvement projects. However, the research evolved into a much more comprehensive study. IAQ established the Designed Improvement Think Tank to study this issue and propose a solution. That group critiqued all of the improvement models currently used frequently by European businesses that were available in the public domain and assessed them for strengths and weaknesses. A composite continual improvement model (CIM) (Figure 27) was developed.

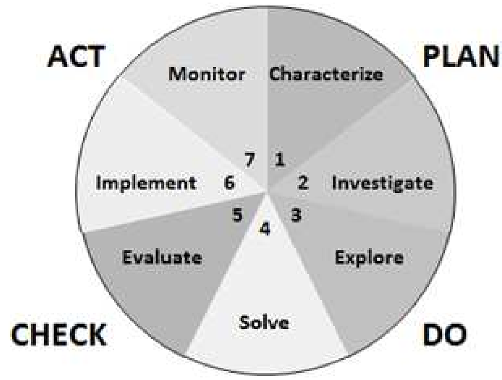

FIGURE 27: The IAQ Continual Improvement Model

The final report on the development phase of this project was presented to EOQ in June 2017 (Watson & Sorqvist, 2017). The CIM model represents the opportunities for improvement associated with the PDCA and Lean Six Sigma models that had been reported by Watson and DeYong (2010, pp. 66-84), born in 1974. The suitability for applying CIM to the Bayesian moment model (see Figure 28) represents another interesting opportunity for useful research because this broadened decision model may help to enlighten how improvements can be made to the process of EDM.

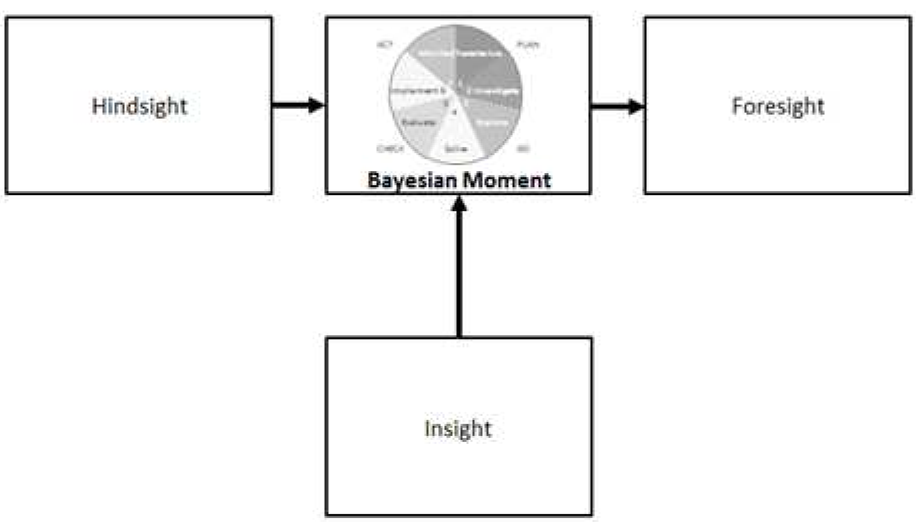

FIGURE 28: CIM Infused Into the Bayesian Moment Model

9.5 Collaborative Analytics and the Definition of Meaningful Relationships

We live in an age of big data where information multiplies at an “exponential plus” rate due to the distribution of digital data capture systems and automated information processing on the Internet. As data proliferates in this age, interpretation of data will become a major issue as analysts coming from different social systems may impute different meanings to similar events and observations. In fact, complexity associated with many dimensions is likely to create human problems. One psychology researcher, Camille S. DeBell (2008), born in 1964, observed that there is a major impact on the way that people work in the face of the growing complexity caused by all of this technology. “Because of the increasing complexity of work in people’s lives and the rapid ways in which work is changing, it is likely that all applied psychologists will need greater content knowledge about work to assist clients with issues related to work choice, entry, and adjustment” (DeBell, 2008, p. 325). The human problems of information overload, alienation, anxiety, and depression need to be studied for information intensive-environments where choices are driven by processing massive databases that are unknowable without the support of information systems. Confidence in human decision making may be undermined if data integrity cannot be assured in the observation and recording of the events that are registered as raw data. An approach to integrate humanity and informative systems to derive profound knowledge is called “collaborative analytics.”

Collaborative analytics (Sawhney, 2008) represents a convergence of: accessible, massive databases; unlimited computing power through cloud resources; highly flexible artificial intelligence algorithms for searching and sorting data according to data patterns established through multi-variable attribute analytics and text mining as well as consideration of their special temporal attributes These need to be coupled with a wide variety of available analytics which can be commented upon and interpreted by a distributed network of human analysts. In this model, the data, processing power, and the analysts, are likely to be distributed geographically. The analytical methods will need to be structured to support the theory of profound knowledge coupled with the definitions initiated by Barnard (1938) and Drucker (1954) for cooperation as a basis for developing refined meaning to create a comprehensive approach to collaboration. Application of Barnard's (1938) hierarchy of knowledge (pp. 193-195, 201-211) coupled with Taguchi's (1986) rules of analytical interpretation provide ways to evaluate sources of data in terms of the degree of influence that it has for shaping collaborative decisions. Taguchi observes that there are three different ways to value the "best" performance in a measure: smaller value is better (e.g., cycle time), bigger value is better (e.g., productivity), and "nominal is best" (e.g., on-time-delivery). All performance measures may be characterized as using one of these three rules for determining the desired direction of the function in EDM (Taguchi, 1986, pp. 113-120).

How can collaborative analytics be applied to reduce common cause variation and drive the improvement of systems performance for achieving consistently predictable outcomes? The response mechanism of a system to dynamic change can be managed according to any of three performance goals. The system might be made robust so that it returns to its original condition after the impact of variation in a resilient response to anticipate causal influence. Another option would be for the system to react like a biological system and develop resilience so that it resists any future infection of unwanted variation. Finally, the system might grow stronger following the intrusion of variation by learning how to cope with this change and establishing rules for its action in future states, which is called an "anti-fragile" response by Nassim Nicholas Taleb (2012), who was born in 1960, and it represents a learned, adaptive response taken by an intelligent system reacting to external stimulation as part of its normal learning practice. The choice of the strategy for improvement depends on the integration of a multidisciplinary choice as to what would be best for the system. Collaborative analytics should assure that the business, engineer, and customer voices, as well as historical experience, are all heard and considered in the EDM process.

9.6 Statistical Storytelling and the Pursuit of Causal Relationships

Tukey (1977) coined the term exploratory data analysis, and Shainin (1993) applied his method of variables search to discover the causes of quality problems. These methods can be blended to form a modern approach to the pursuit of causality through analytics that can be called "little data" analytics compared to the big data emphasis of massive database queries. A little data approach blends graphical visualization with categorical classification, enumerative and analytic statistical methods, and customer requirements to develop a statistical story to define the case for describing what is happening within the Bayesian moment of a process (Watson, 2018). A process called statistical storytelling may be used to explain the results of a systematic data inquiry into the interpretation of historical data using a combination of analytical methods that blends together different unique perspectives to conduct a data query of little sets of data. One problem noted with big data is that the size of the data set can reduce the effect confidence interval around a decision statistic because the standard error gets much smaller as the sample size increases. This reduction generates higher levels of correlation among the analysis variables than would be found in the analysis of smaller data sets. This can create a "false positive" relationship. Other factors such as co-linearity and confounded data relationships also can create interpretation problems. The American Statistical Association recently has declared that the p-value (calculation of the probability of the calculation being statistically significant) should not be used exclusively for determining the statistical significance among relationships. Thus, understanding how all factors apply in an EDM requires multiple perspectives and an explanatory capability that is more profound than the former rule of significance testing (ASA, 2018). Seeking causal explanations of observed phenomena requires that an analyst obtain profound knowledge of the conditions as well as multidisciplinary input for the interpretation of data. Decisions presented to aid in EDM also must be explained in language that permits interpretation according to the lowest common denominator of the executives' experiences; a story must be told from the data that makes sense of the situation. To achieve this capability, collaborative analytics need to be presented to management. How to perform this analysis and interpretation of observations within the Bayesian moment would be another excellent opportunity for future research.

9.7 Improving Improvement

Although the approach for achieving transformation was not specified fully by Deming when he presented his system of profound knowledge in 1993, a mental model for application of newly proposed theory of profound knowledge has been developed based on the conclusions that were drawn from the grounded research into the historical roots of that system. The model of the Bayesian moment supports the theory of profound knowledge and provides a framework for future research into EDM (see Figure 29).

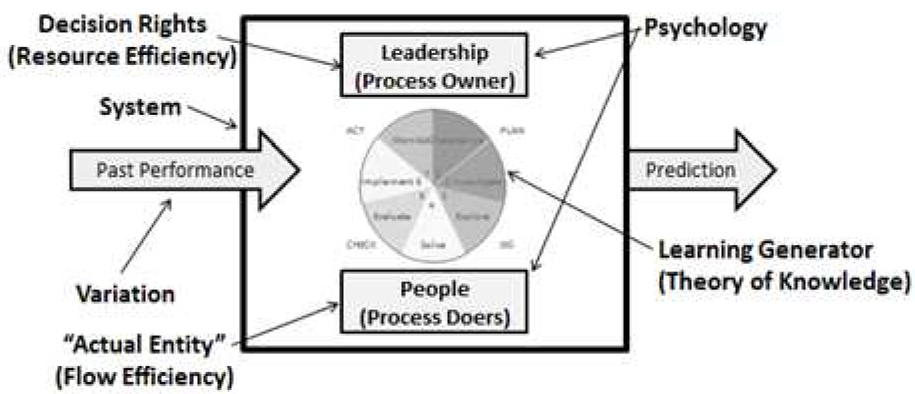

FIGURE 29: The Theory of Profound Knowledge Within the Bayesian Moment

The importance of increasing executive understanding of its decisions has accelerated with the pursuit of ubiquitous data collection stimulated by movements for Industry 4.0 and the Internet of Things, which will place sensors at data-collectable locations to generate even more data for decisions. Simon's (1945) bounded rationality identified three areas of concentration for achieving improvement in EDM: data integrity, competence of the decision maker, and urgency of the decision (p. 119). As data becomes more pervasive, the urgency of dealing with its meanings will increase. Data integrity can be improved through technology and statistical methods. This makes the competence of the decision maker the critical opportunity for improvement. The motivations which stimulated this dissertation and required this into these issues have been satisfied.

What should be done to improve and how should executives seek to define their work in Gemba 2 as it relates to Gemba 1? The summary in Table 31 should help to clarify how the two gemba distinguish among the various categories of improvement activities:

Management System	Type of Improvement	Pace of Change	Thought Leadership	Initiation of Change	Critical Flow Managed
Nichijo Kanri [Gemba 1]	Incremental	Evolutionary	Worker	Self-Directed	Operational
Hoshin Kanri {Gemba 2]	Breakthrough	Revolutionary	Management	Strategy-Directed	Resource

TABLE 31: Comparison of Incremental and Breakthrough Improvement

A recent article in a popular business magazine cited this problem by referring the way that Deming characterized the approach to problems within the Bayesian moment.

> Without data you're just a person with an opinion. The words of W. Edwards Deming, patron saint of the quality movement, reflect postwar naiveté about the possibility of blank-slate objectivity which in many fields was tinged with outright scientism. In science, you don't want opinions, you want to look at the facts, and these must be objective. Your opinion doesn't count. Whether you like it or not, the Earth revolves

> around the Sun, and you know it by looking at the facts informed by repeated experiments (Jones & Silberzahn, 2016).

This article didn't interpret Deming (1986; 1994) exactly correctly when mentioning his ideas from his last two books. Although Deming encouraged empirical foundations in his pursuit of profound knowledge, he was not limited by this positivist approach. Perhaps he would agree with Glasser (1998) that "all is data" (p. 8) and that pertinent factual evidence also includes human perceptions which are the basis for human behavior. The article continued by adding a perspective from Drucker:

> This insight is not new. Indeed, in the field of management, Peter Drucker remarked long ago that: Executives who make effective decisions know that one does not start with facts. One starts with opinions… The understanding that underlies the right decision grows out of the clash and conflict of divergent opinions and out of serious consideration of competing alternatives. To get the facts first is impossible. There are no facts unless one has a criterion of relevance (Jones & Silberzahn, 2016).

Interestingly, this contemporary article echoes the same issue that has been called the "justified true belief" argument. It was described by the essays of Clifford (1877) ("Ethics of Belief") and James (1899) ("Will to Believe") in the late 1800's. This revisitation of the dissertation's origins illustrates the continuing need to improve understanding of the mechanisms by which executives can make better decisions. This observation further supports the potential value of future research. At this time, there is no accepted profound knowledge related to this matter–just a new pathway for conducting further inquiries.

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APPENDIX A

SURVEY SOLICITATION EMAIL FORM

Dear Quality Colleague,

You are receiving this email from Gregory H. Watson who is conducting his PhD dissertation research in Industrial Engineering and Management on the topic: "The Theory and Practice of Profound Knowledge: An Inquiry into Quality and Strategy Management" at Oklahoma State University.

This email requests your participation in an expert review of the dissertation subject matter. Details of this request follow below:

Purpose: The purpose of the research study is to conduct a grounded research investigation of the System of Profound Knowledge that was proposed by W. Edwards Deming in his 1992 book *The New Economics* (Cambridge, MA: MIT Press). The investigation evaluated documentation as published into thinking pathways that are derived from Deming's theory and historical inquiry regarding evolution of meaning in these pathways has created a proposed "Theory of Profound Knowledge" which is postulated in the dissertation. The purpose of this research is to assess the validity, relevance and applicability of the proposed theory based upon the insights of an expert panel who are recognized experts in the field of quality management.

What to Expect: This research will be administered online. Participation in this research will involve completion of a single questionnaire. This questionnaire will ask you to address eight topics about the dissertation. Each question will ask for your opinions about topics addressed in the dissertation and may take you several hours to complete, depending on the time you wish to invest in studying the dissertation and formulating free-text commentary to the questions. The topics of this inquiry will be as follows:

- Validity of the dissertation assumptions
- Clarity of the operational definitions proposed in the dissertation
- Innovativeness of the research question posed
- Relevance of the historical treads cited in the literature search
- Completeness of the background literature investigation
- Value of the proposed Theory of Profound Knowledge
- Applicability of this theory to the practice of quality management and beyond
- Opinions about the proposed future research

Risks: There are no risks associated with this project which are expected to be greater than those ordinarily encountered with the submission of an academic article for publication in a journal.

Benefits: There may be no direct benefits to you; however, as your submission will be included in a verbatim form as an appendix to the dissertation but without any identifying information that will link it to you as an individual. This should be considered the equivalent of the submission of an academic paper for publication for blind peer review. All responses will remain anonymous. However, as a side benefit, you will gain a new appreciation of the historical development of the body of quality knowledge based as developed through grounded research study as presented in the dissertation.

Compensation: There will be no direct or indirect compensation for your participation in this research.

Your Rights and Confidentiality: Your participation in this research is voluntary. There is no penalty for refusal to participate, and you are free to withdraw your consent and participation in this project at any time. All submissions will be published in an appendix to the dissertation and available in open literature; however, your name and organizational affiliation will be identified as a participant without any reference to your specific response which will remain confidential.

Contact: You may contact any of the researchers at the following addresses and phone numbers, should you desire to discuss your participation in the study and/or request information about the results of the study:

Gregory H. Watson, PhD. Candidate
Email: greg@excellence.fi
Phone: +358-50-577-9777

Dr. Camille F. DeYong, Advisor
Department of Industrial Engineering and Management
Oklahoma State University
322 Engineering North
Stillwater, OK 74078
Email: camille.deyong@okstate.edu
Phone: +1-405-744-9133

If you have questions about your rights as a research volunteer, you may contact the IRB Office at 223 Scott Hall, Stillwater, OK 74078, 405-744-3377 or irb@okstate.edu.

It is recommended that you print a copy of this consent page for your records before you begin to respond to the questionnaire.

If you choose to participate: Please click here to access the survey. A copy of the draft dissertation has been attached to the solicitation email. Please initiate the link to permit your anonymous response to the questions which represents the extent of your participation in this research. All participants will be sent a copy of the final published dissertation for their personal library.

Thank you for your consideration of this request.

Sincerely,

Greg

APPENDIX B

PARTICIPATION INFORMATION AND CONSENT

Title: The Theory and Practice of Profound Knowledge

Investigator:

Gregory H. Watson, PhD. Candidate
Oklahoma State University
Department of Industrial Engineering and Management
Stillwater, OK 74078

Purpose: The purpose of the research study is to conduct a grounded research investigation of the System of Profound Knowledge that was proposed by W. Edwards Deming in his 1992 book *The New Economics* (Cambridge, MA: MIT Press). The investigation evaluated documentation as published into thinking pathways that are derived from Deming's theory and historical inquiry regarding evolution of meaning in these pathways has created a proposed "Theory of Profound Knowledge" which is postulated in the dissertation. The purpose of this research is to assess the validity, relevance and applicability of the proposed theory based upon the insights of an expert panel who are recognized experts in the field of quality management.

What to Expect: This research will be administered online. Participation in this research will involve completion of a single questionnaire. This questionnaire will ask you to address eight topics about the dissertation. Each question will ask for your opinions about topics addressed in the dissertation and may take you several hours to complete, depending on the time you wish to invest in studying the dissertation and formulating free-text commentary to the questions. The topics of this inquiry will be as follows:

- Validity of the dissertation assumptions
- Clarity of the operational definitions proposed in the dissertation
- Innovativeness of the research question posed
- Relevance of the historical treads cited in the literature search
- Completeness of the background literature investigation
- Value of the proposed Theory of Profound Knowledge
- Applicability of this theory to the practice of quality management and beyond
- Opinions about the proposed future research

Risks: There are no risks associated with this project which are expected to be greater than those ordinarily encountered with the submission of an academic article for publication in a journal.

Benefits: There may be no direct benefits to you; however, as your submission will be included in a verbatim form as an appendix to the dissertation but without any identifying information that will link it to you as an individual. This should be considered the equivalent of the submission of an academic paper for publication for blind peer review. All responses will remain anonymous. However, as a side benefit, you will gain a new appreciation of the historical development of the body of quality knowledge based as developed through grounded research study as presented in the dissertation.

Compensation: There will be no direct or indirect compensation for your participation in this research.

Your Rights and Confidentiality: Your participation in this research is voluntary. There is no penalty for refusal to participate, and you are free to withdraw your consent and participation in this project at any time. All submissions will be published in an appendix to the dissertation and available in open literature; however, your name and organizational affiliation will be identified as a participant without any reference to your specific response which will remain confidential.

Contact: You may contact any of the researchers at the following addresses and phone numbers, should you desire to discuss your participation in the study and/or request information about the results of the study:

Gregory H. Watson, PhD. Candidate
Email: greg@excellence.fi
Phone: +358-50-577-9777

Dr. Camille F. DeYong, Advisor
Department of Industrial Engineering and Management
Oklahoma State University
322 Engineering North
Stillwater, OK 74078
Email: camille.deyong@okstate.edu
Phone: +1-405-744-9133

If you have questions about your rights as a research volunteer, you may contact the IRB Office at 223 Scott Hall, Stillwater, OK 74078, 405-744-3377 or irb@okstate.edu.

It is recommended that you print a copy of this consent page for your records before you begin to respond to the questionnaire.

If you choose to participate: Please click here to access the survey. A copy of the draft dissertation has been attached to the solicitation email. Please initiate the link to permit your anonymous response to the questions which represents the extent of your participation in this research. All participants will be sent a copy of the final published dissertation for their personal library.

Participant Information:

Participant Age Group (choose one):

___ Less than 40

___ 40 to 65

___ Over 65

Participant Career (choose one that is dominant):

___ Academic

___ Practitioner

Participant Highest Educational Degree:

___ Bachelors

___ Masters

___ Doctorate

Particpant Professional Certification:

___ Professional Engineer (or equivalent)

___ Master Black Belt (or equivalent)

___ Other (specify) ______________________________

___ None

1. Statement: The stated assumptions of the dissertation possess a necessary and sufficient degree of validity.

Operational Definition of Key Terms:

- Validity: the extent to which the assumptions support the fundamental logic that is required for initiation of the research question.

Please indicate your strength of agreement with the above statement by selecting the appropriate level of agreement on the following scale:

Scale of Agreement:

Most strongly disagree	Strongly disagree	Weakly disagree	Neutral	Weakly agree	Strongly agree	Most strongly agree
1	2	3	4	5	6	7

Please provide your comments about any of the assumptions that you believe need to be questioned here describing the rationale for your concern or area for improvement:

-
-
-
-
-

2. Statement: Operational definitions proposed in the dissertation provide ambiguity-free meaning and identify the scope of the term defined.

Operational Definition of Key Terms:

- Clarity: clearness or lucidity in explanation so that perception and understanding is readily communicated; freedom from confusion, ambiguity or indistinctness in meaning.

Please indicate your strength of agreement with the above statement by selecting the appropriate level of agreement on the following scale:

Scale of Agreement:

Most strongly disagree	Strongly disagree	Weakly disagree	Neutral	Weakly agree	Strongly agree	Most strongly agree
1	2	3	4	5	6	7

Please provide your comments about any of the definitions that you believe need to be redefined here describing the rationale for your concern or area for improvement:

-
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-
-

3. Statement: The research question posed in the dissertation is exceptionally innovative compared to the prior body of knowledge.

Operational Definition of Key Terms:

- Innovativeness: the introduction of a new idea, method or theory that meets new requirements, satisfies unarticulated needs, or expands existing knowledge.

Please indicate your strength of agreement with the above statement by selecting the appropriate level of agreement on the following scale:

Scale of Agreement:

Most strongly disagree	Strongly disagree	Weakly disagree	Neutral	Weakly agree	Strongly agree	Most strongly agree
1	2	3	4	5	6	7

Please provide your comments about any of the innovativeness of the research question that you believe need to be reassessed, describing the rationale for your concern or area for improvement:

-
-
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4. Statement: The identified historical treads cited as “thinking pathways” define relevant subjects for inquiry in the literature search

Operational Definition of Key Terms:

- Relevance: Pertinent to the matter at hand, important for the full understanding of the development of the concepts and are related to the subject at hand.

Please indicate your strength of agreement with the above statement by selecting the appropriate level of agreement on the following scale:

Scale of Agreement:

Most strongly disagree	Strongly disagree	Weakly disagree	Neutral	Weakly agree	Strongly agree	Most strongly agree
1	2	3	4	5	6	7

Please provide your comments about any of the innovativeness of the research question that you believe need to be reassessed, describing the rationale for your concern or area for improvement:

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5. Statement: The background literature investigation represents a complete enumeration and description of the key literature contributions for each of the thinking pathways that are identified as contributing to the Theory of Profound Knowledge.

Operational Definition of Key Terms:

- Completeness: a comprehensive, inclusive enumeration of parts, items or elements that lacks nothing; an exhaustive compilation of the whole or the entire subset of components that contains all appropriate parts or rational sub-groups.

- Significance: Items that are worthy of attention due to their importance, seriousness, gravity, or consequences.

Please indicate your strength of agreement with the above statement by selecting the appropriate level of agreement on the following scale:

Scale of Agreement:

Most strongly disagree	Strongly disagree	Weakly disagree	Neutral	Weakly agree	Strongly agree	Most strongly agree
1	2	3	4	5	6	7

Please provide your comments about any of the completeness of the literature search and the significance of the documents that are identified and described as contributing to the advancement of knowledge in the thinking pathways. Comment about any of these areas that you believe have missing significant contributions, describing the rationale for your concern or recommended areas for improvement:

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-

6. Statement: The proposed Theory of Profound Knowledge offers significant value for the explanation of the transformation process and is represents a significant contribution to the advancement of the System of Profound Knowledge as proposed by W. Edwards Deming.

Operational Definition of Key Terms:

- Value: The degree of worthiness or usefulness of something. The benefit that may be gained through the relative merit or utility of a proposition, item, or belief.

Please indicate your strength of agreement with the above statement by selecting the appropriate level of agreement on the following scale:

Scale of Agreement:

Most strongly disagree	Strongly disagree	Weakly disagree	Neutral	Weakly agree	Strongly agree	Most strongly agree
1	2	3	4	5	6	7

Please comments about the value of the proposed Theory of Profound Knowledge with respect to its value in understanding the process of managing the transformation of an organization from historical knowledge through the Bayesian Moment to create the predictive analytics necessary for developing a probabilistic understanding of the future. Comment about any areas that you believe fails to deliver pragmatic value or conceptual understanding of this transformation process and describe the rationale for your concern and any recommendations for improvement:

-
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7. Statement: The Theory of Profound Knowledge as presented in the dissertation is applicable to the advancement of the current practice of quality management and will be significant for developing further advancements to the quality management body of knowledge.

Operational Definition of Key Terms:

- Applicability: The proposed theory represents a systematic approach that involves the practical application of relevant, suitable knowledge that provides an approach to the substantial issue of estimating future states of organizational performance, defining how to effect the transformation, and identifying the system and human factors that will influence the transformation.

- Quality: The persistent pursuit of goodness, coupled tightly with the relentless avoidance of badness as determined from the perspective of the ultimate customer.

- Quality management: The administration and oversight of the activities and the tasks necessary to design, develop, and maintain a desired level of performance excellence necessary to achieve quality in the content delivered to customers and the process by which that content is delivered.

Please indicate your strength of agreement with the above statement by selecting the appropriate level of agreement on the following scale:

Scale of Agreement:

Most strongly disagree	Strongly disagree	Weakly disagree	Neutral	Weakly agree	Strongly agree	Most strongly agree
1	2	3	4	5	6	7

Please comments about the value of the proposed Theory of Profound Knowledge with respect to its value in understanding the process of managing the transformation of an organization from historical knowledge through the Bayesian Moment to create the predictive analytics necessary for developing a probabilistic understanding of the future. Comment about any areas that you believe fails to deliver pragmatic value or conceptual understanding of this transformation process and describe the rationale for your concern and any recommendations for improvement:

-
-
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-

8. Statement: The proposed future research areas represent significant opportunities for this theory to be advanced and make further contributions for the advancement of the related body of knowledge.

Operational Definition of Key Terms:

- Future research: The development of new directions for research based upon findings of the current inquiry and overcoming past limitations in the field of knowledge or by extending the current inquiry to address new circumstances.

Please indicate your strength of agreement with the above statement by selecting the appropriate level of agreement on the following scale:

Scale of Agreement:

Most strongly disagree	Strongly disagree	Weakly disagree	Neutral	Weakly agree	Strongly agree	Most strongly agree
1	2	3	4	5	6	7

Please comments about the proposed directions for future research and identify any areas that you believe need to be expanded or revised describing the rationale for your concern and any recommendations for improvement:

-
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-

APPENDIX C

INSTITUTIONAL REVIEW BOARD APPROVAL

Date:	Friday, January 26, 2018
IRB Application No	EG1713
Proposal Title:	Theory and Practice of Profound Knowledge - Doctoral Dissertation
Reviewed and Processed as:	Exempt

Status Recommended by Reviewer(s): Approved Protocol Expires: 1/25/2021

Principal Investigator(s):

Gregory Watson	Camille F DeYong
	322 Eng N
Stillwater, OK 74078	Stillwater, OK 74078

The IRB application referenced above has been approved. It is the judgment of the reviewers that the rights and welfare of individuals who may be asked to participate in this study will be respected, and that the research will be conducted in a manner consistent with the IRB requirements as outlined in section 45 CFR 46.

☐ The final versions of any printed recruitment, consent and assent documents bearing the IRB approval stamp are attached to this letter. These are the versions that must be used during the study.

As Principal Investigator, it is your responsibility to do the following:

1. Conduct this study exactly as it has been approved. Any modifications to the research protocol must be submitted with the appropriate signatures for IRB approval. Protocol modifications requiring approval may include changes to the title, PI advisor, funding status or sponsor, subject population composition or size, recruitment, inclusion/exclusion criteria, research site, research procedures and consent/assent process or forms.
2. Submit a request for continuation if the study extends beyond the approval period. This continuation must receive IRB review and approval before the research can continue.
3. Report any adverse events to the IRB Chair promptly. Adverse events are those which are unanticipated and impact the subjects during the course of the research; and
4. Notify the IRB office in writing when your research project is complete.

Please note that approved protocols are subject to monitoring by the IRB and that the IRB office has the authority to inspect research records associated with this protocol at any time. If you have questions about the IRB procedures or need any assistance from the Board, please contact Dawnett Watkins 219 Scott Hall (phone: 405-744-5700, dawnett.watkins@okstate.edu).

Sincerely,

Hugh Crethar, Chair
Institutional Review Board

APPENDIX D

EXPERT PANEL SURVEY RESPONSE SUMMARY

Respondent	Information	Response
1	Age Group	40-60
	Professional Category	Practitioner
	Highest Degree	Doctorate
	Professional Qualification	Professional Engineer (or equivalent)
	Affirmation Statement #1 Rating–Validity	7 – Most Strongly Agree
	Affirmation Statement #2 Rating–Clarity	6 – Strongly Agree
	Affirmation Statement #3 Rating–Innovativeness	6 – Strongly Agree
	Affirmation Statement #4 Rating–Relevance	6 – Strongly Agree
	Affirmation Statement #5 Rating–Completeness and Significance	6 – Strongly Agree
	Affirmation Statement #6 Rating–Value	6 – Strongly Agree
	Affirmation Statement #7 Rating–Applicability	6 – Strongly Agree

2	Age Group	Over 60
	Professional Category	Practitioner
	Highest Degree	Doctorate
	Professional Qualification	Master Black Belt (or equivalent)
	Affirmation Statement #1 Rating–Validity	3 – Weakly Disagree
	Affirmation Statement #2 Rating–Clarity	7 – Most Strongly Agree
	Affirmation Statement #3 Rating–Innovativeness	7 – Most Strongly Agree
	Affirmation Statement #4 Rating–Relevance	7 – Most Strongly Agree
	Affirmation Statement #5 Rating–Completeness and Significance	3 – Weakly Disagree
	Affirmation Statement #6 Rating–Value	7 – Most Strongly Agree
	Affirmation Statement #7 Rating–Applicability	5 – Weakly Agree

3	Age Group	40-60
	Professional Category	Academic
	Highest Degree	Doctorate
	Professional Qualification	None
	Affirmation Statement #1 Rating–Validity	6 – Strongly Agree
	Affirmation Statement #2 Rating–Clarity	6 – Strongly Agree
	Affirmation Statement #3 Rating–Innovativeness	6 – Strongly Agree
	Affirmation Statement #4 Rating–Relevance	6 – Strongly Agree
	Affirmation Statement #5 Rating–Completeness and Significance	6 – Strongly Agree
	Affirmation Statement #6 Rating–Value	6 – Strongly Agree
	Affirmation Statement #7 Rating–Applicability	6 – Strongly Agree

4	Age Group	Over 60
	Professional Category	Academic
	Highest Degree	Doctorate
	Professional Qualification	None
	Affirmation Statement #1 Rating–Validity	6 – Strongly Agree
	Affirmation Statement #2 Rating–Clarity	6 – Strongly Agree
	Affirmation Statement #3 Rating–Innovativeness	6 – Strongly Agree
	Affirmation Statement #4 Rating–Relevance	6 – Strongly Agree
	Affirmation Statement #5 Rating–Completeness and Significance	6 – Strongly Agree
	Affirmation Statement #6 Rating–Value	6 – Strongly Agree
	Affirmation Statement #7 Rating–Applicability	6 – Strongly Agree

5	Age Group	40-60
	Professional Category	Practitioner
	Highest Degree	Master’s
	Professional Qualification	Master Black Belt (or equivalent)
	Affirmation Statement #1 Rating–Validity	7 – Most Strongly Agree
	Comment	
	Affirmation Statement #2 Rating–Clarity	7 – Most Strongly Agree
	Affirmation Statement #3 Rating–Innovativeness	7 – Most Strongly Agree
	Affirmation Statement #4 Rating–Relevance	7 – Most Strongly Agree
	Affirmation Statement #5 Rating–Completeness and Significance	7 – Most Strongly Agree
	Affirmation Statement #6 Rating–Value	7 – Most Strongly Agree
	Affirmation Statement #7 Rating–Applicability	7 – Most Strongly Agree

6	Age Group	40-60
	Professional Category	Practitioner
	Highest Degree	Doctorate
	Professional Qualification	Master Black Belt (or equivalent)
	Affirmation Statement #1 Rating–Validity	6 – Strongly Agree
	Affirmation Statement #2 Rating–Clarity	5 – Weakly Agree
	Affirmation Statement #3 Rating–Innovativeness	6 – Strongly Agree
	Affirmation Statement #4 Rating–Relevance	7 – Most Strongly Agree
	Affirmation Statement #5 Rating–Completeness and Significance	6 – Strongly Agree
	Affirmation Statement #6 Rating–Value	6 – Strongly Agree
	Affirmation Statement #7 Rating–Applicability	6 – Strongly Agree

7	Age Group	40-60
	Professional Category	Academic
	Highest Degree	Doctorate
	Professional Qualification	Master Black Belt (or equivalent)
	Affirmation Statement #1 Rating–Validity	6 – Strongly Agree
	Affirmation Statement #2 Rating–Clarity	6 – Strongly Agree
	Affirmation Statement #3 Rating–Innovativeness	5 – Weakly Agree
	Affirmation Statement #4 Rating–Relevance	6 – Strongly Agree
	Affirmation Statement #5 Rating–Completeness and Significance	4 – Neutral
	Affirmation Statement #6 Rating–Value	6 – Strongly Agree
	Affirmation Statement #7 Rating–Applicability	6 – Strongly Agree

8	Age Group	40-60
	Professional Category	Academic
	Highest Degree	Doctorate
	Professional Qualification	Master Black Belt (or equivalent)
	Affirmation Statement #1 Rating–Validity	7 – Most Strongly Agree
	Affirmation Statement #2 Rating–Clarity	6 – Strongly Agree
	Affirmation Statement #3 Rating–Innovativeness	6 – Strongly Agree
	Affirmation Statement #4 Rating–Relevance	7 – Most Strongly Agree
	Affirmation Statement #5 Rating–Completeness and Significance	7 – Most Strongly Agree
	Affirmation Statement #6 Rating–Value	7 – Most Strongly Agree
	Affirmation Statement #7 Rating–Applicability	6 – Strongly Agree

9	Age Group	Over 60
	Professional Category	Academic
	Highest Degree	Doctorate
	Professional Qualification	Master Black Belt (or equivalent)
	Affirmation Statement #1 Rating–Validity	6 – Strongly Agree
	Affirmation Statement #2 Rating–Clarity	6 – Strongly Agree
	Affirmation Statement #3 Rating–Innovativeness	6 – Strongly Agree
	Affirmation Statement #4 Rating–Relevance	5 – Weakly Agree
	Affirmation Statement #5 Rating–Completeness and Significance	5 – Weakly Agree
	Affirmation Statement #6 Rating–Value	5 – Weakly Agree
	Affirmation Statement #7 Rating–Applicability	5 – Weakly Agree

10	Age Group	40-60
	Professional Category	Academic
	Highest Degree	Doctorate
	Professional Qualification	None
	Affirmation Statement #1 Rating–Validity	6 – Strongly Agree
	Affirmation Statement #2 Rating–Clarity	6 – Strongly Agree
	Affirmation Statement #3 Rating–Innovativeness	6 – Strongly Agree
	Affirmation Statement #4 Rating–Relevance	6 – Strongly Agree
	Affirmation Statement #5 Rating–Completeness and Significance	7 – Most Strongly Agree
	Affirmation Statement #6 Rating–Value	7 – Most Strongly Agree
	Affirmation Statement #7 Rating–Applicability	7 – Most Strongly Agree

11	Age Group	40-60
	Professional Category	Academic
	Highest Degree	Doctorate
	Professional Qualification	Master Black Belt (or equivalent)
	Affirmation Statement #1 Rating–Validity	6 – Strongly Agree
	Affirmation Statement #2 Rating–Clarity	6 – Strongly Agree
	Affirmation Statement #3 Rating–Innovativeness	5 – Weakly Agree
	Affirmation Statement #4 Rating–Relevance	6 – Strongly Agree
	Affirmation Statement #5 Rating–Completeness and Significance	6 – Strongly Agree
	Affirmation Statement #6 Rating–Value	6 – Strongly Agree
	Affirmation Statement #7 Rating–Applicability	6 – Strongly Agree

12	Age Group	Over 60
	Professional Category	Academic
	Highest Degree	Doctorate
	Professional Qualification	None
	Affirmation Statement #1 Rating–Validity	6 – Strongly Agree
	Affirmation Statement #2 Rating–Clarity	7 – Most Strongly Agree
	Affirmation Statement #3 Rating–Innovativeness	5 – Weakly Agree
	Affirmation Statement #4 Rating–Relevance	6 – Strongly Agree
	Affirmation Statement #5 Rating–Completeness and Significance	6 – Strongly Agree
	Affirmation Statement #6 Rating–Value	7 – Most Strongly Agree
	Affirmation Statement #7 Rating–Applicability	5 – Weakly Agree

13	Age Group	Over 60
	Professional Category	Practitioner
	Highest Degree	Doctorate
	Professional Qualification	Master Black Belt (or equivalent)
	Affirmation Statement #1 Rating–Validity	7 – Most Strongly Agree
	Affirmation Statement #2 Rating–Clarity	7 – Most Strongly Agree
	Affirmation Statement #3 Rating–Innovativeness	6 – Strongly Agree
	Affirmation Statement #4 Rating–Relevance	6 – Strongly Agree
	Affirmation Statement #5 Rating–Completeness and Significance	6 – Strongly Agree
	Affirmation Statement #6 Rating–Value	6 – Strongly Agree
	Affirmation Statement #7 Rating–Applicability	6 – Strongly Agree

14	Age Group	Under 40
	Professional Category	Practitioner
	Highest Degree	Master's
	Professional Qualification	Master Black Belt (or equivalent)
	Affirmation Statement #1 Rating–Validity	6 – Strongly Agree
	Affirmation Statement #2 Rating–Clarity	6 – Strongly Agree
	Affirmation Statement #3 Rating–Innovativeness	6 – Strongly Agree
	Affirmation Statement #4 Rating–Relevance	6 – Strongly Agree
	Affirmation Statement #5 Rating–Completeness and Significance	6 – Strongly Agree
	Affirmation Statement #6 Rating–Value	4 – Neutral
	Affirmation Statement #7 Rating–Applicability	6 – Strongly Agree

15	Age Group	Under 40
	Professional Category	Practitioner
	Highest Degree	Bachelor's
	Professional Qualification	Master Black Belt (or equivalent)
	Affirmation Statement #1 Rating–Validity	7 – Most Strongly Agree
	Affirmation Statement #2 Rating–Clarity	7 – Most Strongly Agree
	Affirmation Statement #3 Rating–Innovativeness	6 – Strongly Agree
	Affirmation Statement #4 Rating–Relevance	7 – Most Strongly Agree
	Affirmation Statement #5 Rating–Completeness and Significance	7 – Most Strongly Agree
	Affirmation Statement #6 Rating–Value	6 – Strongly Agree
	Affirmation Statement #7 Rating–Applicability	7 – Most Strongly Agree

16	Age Group	40-60
	Professional Category	Practitioner
	Highest Degree	Bachelor’s
	Professional Qualification	Master Black Belt (or equivalent)
	Affirmation Statement #1 Rating–Validity	7 – Most Strongly Agree
	Affirmation Statement #2 Rating–Clarity	6 – Strongly Agree
	Affirmation Statement #3 Rating–Innovativeness	6 – Strongly Agree
	Affirmation Statement #4 Rating–Relevance	6 – Strongly Agree
	Affirmation Statement #5 Rating–Completeness and Significance	4 – Neutral
	Affirmation Statement #6 Rating–Value	6 – Strongly Agree
	Affirmation Statement #7 Rating–Applicability	6 – Strongly Agree

17	Age Group	40-60
	Professional Category	Practitioner
	Highest Degree	Master’s
	Professional Qualification	Master Black Belt (or equivalent)
	Affirmation Statement #1 Rating–Validity	6 – Strongly Agree
	Affirmation Statement #2 Rating–Clarity	6 – Strongly Agree
	Affirmation Statement #3 Rating–Innovativeness	6 – Strongly Agree
	Affirmation Statement #4 Rating–Relevance	7 – Most Strongly Agree
	Affirmation Statement #5 Rating–Completeness and Significance	7 – Most Strongly Agree
	Affirmation Statement #6 Rating–Value	6 – Strongly Agree
	Affirmation Statement #7 Rating–Applicability	5 – Weakly Agree

18	Age Group	Over 60
	Professional Category	Practitioner
	Highest Degree	Master's
	Professional Qualification	None
	Affirmation Statement #1 Rating–Validity	6 – Strongly Agree
	Affirmation Statement #2 Rating–Clarity	6 – Strongly Agree
	Affirmation Statement #3 Rating–Innovativeness	6 – Strongly Agree
	Affirmation Statement #4 Rating–Relevance	7 – Most Strongly Agree
	Affirmation Statement #5 Rating–Completeness and Significance	7 – Most Strongly Agree
	Affirmation Statement #6 Rating–Value	6 – Strongly Agree
	Affirmation Statement #7 Rating–Applicability	6 – Strongly Agree

19	Age Group	Over 60
	Professional Category	Academic
	Highest Degree	Doctorate
	Professional Qualification	Professional Engineer (or equivalent)
	Affirmation Statement #1 Rating–Validity	7 – Most Strongly Agree
	Affirmation Statement #2 Rating–Clarity	7 – Most Strongly Agree
	Affirmation Statement #3 Rating–Innovativeness	7 – Most Strongly Agree
	Affirmation Statement #4 Rating–Relevance	7 – Most Strongly Agree
	Affirmation Statement #5 Rating–Completeness and Significance	7 – Most Strongly Agree
	Affirmation Statement #6 Rating–Value	7 – Most Strongly Agree
	Affirmation Statement #7 Rating–Applicability	6 – Strongly Agree

20	Age Group	40-60
	Professional Category	Practitioner
	Highest Degree	Master's
	Professional Qualification	Master Black Belt (or equivalent)
	Affirmation Statement #1 Rating–Validity	7 – Most Strongly Agree
	Affirmation Statement #2 Rating–Clarity	7 – Most Strongly Agree
	Affirmation Statement #3 Rating–Innovativeness	7 – Most Strongly Agree
	Affirmation Statement #4 Rating–Relevance	7 – Most Strongly Agree
	Affirmation Statement #5 Rating–Completeness and Significance	7 – Most Strongly Agree
	Affirmation Statement #6 Rating–Value	7 – Most Strongly Agree
	Affirmation Statement #7 Rating–Applicability	6 – Strongly Agree

21	Age Group	Over 60
	Professional Category	Academic
	Highest Degree	Doctorate
	Professional Qualification	Other
	Affirmation Statement #1 Rating–Validity	6 – Strongly Agree
	Affirmation Statement #2 Rating–Clarity	5 – Weakly Agree
	Affirmation Statement #3 Rating–Innovativeness	6 – Strongly Agree
	Affirmation Statement #4 Rating–Relevance	7 – Most Strongly Agree
	Affirmation Statement #5 Rating–Completeness and Significance	6 – Strongly Agree
	Affirmation Statement #6 Rating–Value	6 – Strongly Agree
	Affirmation Statement #7 Rating–Applicability	6 – Strongly Agree

22	Age Group	40-60
	Professional Category	Practitioner
	Highest Degree	Master’s
	Professional Qualification	Master Black Belt (or equivalent)
	Affirmation Statement #1 Rating–Validity	6 – Strongly Agree
	Affirmation Statement #2 Rating–Clarity	6 – Strongly Agree
	Affirmation Statement #3 Rating–Innovativeness	6 – Strongly Agree
	Affirmation Statement #4 Rating–Relevance	6 – Strongly Agree
	Affirmation Statement #5 Rating–Completeness and Significance	7 – Most Strongly Agree
	Affirmation Statement #6 Rating–Value	6 – Strongly Agree
	Affirmation Statement #7 Rating–Applicability	7 – Most Strongly Agree

23	Age Group	Under 40
	Professional Category	Academic
	Highest Degree	Doctorate
	Professional Qualification	Professional Engineer (or equivalent)
	Affirmation Statement #1 Rating–Validity	6 – Strongly Agree
	Affirmation Statement #2 Rating–Clarity	6 – Strongly Agree
	Affirmation Statement #3 Rating–Innovativeness	6 – Strongly Agree
	Affirmation Statement #4 Rating–Relevance	6 – Strongly Agree
	Affirmation Statement #5 Rating–Completeness and Significance	6 – Strongly Agree
	Affirmation Statement #6 Rating–Value	6 – Strongly Agree
	Affirmation Statement #7 Rating–Applicability	6 – Strongly Agree

24	Age Group	Over 60
	Professional Category	Academic
	Highest Degree	Doctorate
	Professional Qualification	Professional Engineer (or equivalent)
	Affirmation Statement #1 Rating–Validity	6 – Strongly Agree
	Affirmation Statement #2 Rating–Clarity	6 – Strongly Agree
	Affirmation Statement #3 Rating–Innovativeness	6 – Strongly Agree
	Affirmation Statement #4 Rating–Relevance	6 – Strongly Agree
	Affirmation Statement #5 Rating–Completeness and Significance	6 – Strongly Agree
	Affirmation Statement #6 Rating–Value	6 – Strongly Agree
	Affirmation Statement #7 Rating–Applicability	6 – Strongly Agree

VITA

Gregory H. Watson

Candidate for the Degree of

Doctor of Philosophy

Thesis: THE THEORY AND PRACTICE OF PROFOUND KNOWLEDGE: AN INQUIRY INTO QUALITY AND STRATEGY MANAGEMENT

Major Field: Industrial Engineering and Management

Biographical:

Education:

Completed the requirements for the Doctor of Philosophy in Industrial Engineering and Management at Oklahoma State University, Stillwater, Oklahoma in May 2018

Completed the requirements for the Master of Science in Industrial Engineering at Oklahoma State University, Stillwater, Oklahoma, in 2003

Completed the requirements for the Master of Arts in Legal Studies at Antioch University, Washington, DC in 1985

Completed the requirements for the Master of Science in Systems Management at the University of Southern California, Los Angeles, California in 1975

Completed the requirements for the Bachelor of Arts in Philosophy at Taylor University, Upland, Indiana, in 1970

Experience:

- Chairman, Business Excellence Solutions (1994-Present)
- Vice President, Quality, Xerox (1992-1994)
- Vice President, American Productivity & Quality Center (1991-1992)
- Director, Corporate Quality, Compaq Computer Corporation (1989-1991)
- Program Manager, Corporate Quality, Hewlett-Packard (1984-1889)
- Lieutenant Commander, United States Navy (1971-1983)

Professional Memberships:

- Academician, International Academy for Quality
- Fellow, Institute for Industrial and Systems Engineers
- Fellow, American Society for Quality
- Fellow, International Statistical Institute
- Fellow, Royal Statistical Society